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WADC TECHNICAL NOTE 57-390

ACOUSTICAL EVALUATION OF F-102 PRODUCTION SILENCER

CONVAIR, SAN DIEGO

DAVID N. KEAST

AND THE STAFF OF BOLT BERANEK AND NEWMAN INC.

NOVEMBER 1961

CONTRACT No. AF 33(616)-3938

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AEROSPACE MEDICAL LABORATORY
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
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NOTICES

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FOREWORD

This report was prepared by Bolt Beranek and Newman Inc., Cambridge, Massachusetts, under Contract No. AF 33(616)-3938, for the Aerospace Medical Laboratory, Aeronautical Systems Division, in support of Project 7210, "Human Response to Vibratory Energy," Task 71708, "Investigation of Physical Structures and Their Components with Respect to Their Characteristics for Acoustic Energy Reception, Transmission, and Reduction." Mr. R. N. Hancock was the task engineer. Technical supervision of the preparation of this report was the responsibility of Mr. R. N. Hancock, Captain R. G. Hansen, Lt. L. O. Hoeft, and Dr. H. E. von Gierke, Bioacoustics Branch, Biomedical Laboratory, Aerospace Medical Laboratory. Personnel participating in the evaluation from Bolt Beranek and Newman Inc. were: W. J. Galloway, R. E. Galloway, R. M. Hoover, and D. N. Keast.

ABSTRACT

The F-102 production silencer enclosure at Convair-San Diego has been evaluated acoustically. This silencer is similar to a turbojet engine test cell, but is designed to enclose a complete aircraft. Measurements of sound pressure level in and around the silencer are reported, and the noise reductions of the various elements of the acoustical treatment, as well as the noise reduction of the silencer as a whole, are determined. The results indicate that the average insertion-loss noise reduction of the silencer at 250 feet increases from about 20 db in the 20-75 cps band to somewhat greater than 50 db for all frequencies above 300 cps.

PUBLICATION REVIEW

Jos M Quashnock

JOS. M. QUASHNOCK
Colonel, USAF, MC
Chief, Biomedical Laboratory
Aerospace Medical Laboratory

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SECTION I

INTRODUCTION

This report presents the results of an acoustical evaluation of the "production silencers"* at Convair, San Diego, which were designed to enclose an F-102 or F-106 aircraft during ground run-up operations. Detailed measurements have been made to determine the acoustical effectiveness of the primary and secondary air intake, and exhaust acoustical treatments, and the walls and doors of the structure. In addition, studies were made to determine the acoustical effectiveness of the silencer as a whole. These data were obtained during an acoustical survey at Convair, San Diego on 16-17 August 1957.

Measurements of the noise reduction of all the individual elements of the acoustical treatments were made with an explosive noise source (XNS). Many of these measurements were repeated with a J57-P-23 engine, operating in an F-102A aircraft, as a noise source. In addition, measurements of sound pressure level were obtained on a semicircular traverse 250 ft from the silencer during engine operation. Finally, sound pressure levels were measured over the primary and

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* Designed and constructed by Koppers Company, Inc., Metal Products Division, Sound Control Department, Baltimore 3, Maryland

secondary air intake openings, the exhaust opening, and at other close-in positions during engine operation.

SECTION II

DESCRIPTION OF MEASUREMENT SITE AND PRODUCTION SILENCERS

A. Description of Measurement Site

A plan of the area in which the measurements were conducted is shown on Fig 1. Three of the ground run-up enclosures are located to one side of the final, pre-flight check-out area which constitutes a part of the Convair production facility in San Diego, California. The measurements were performed on Cell A, the westernmost of the three. On a circle of 250 ft radius from the center of the cell, data were obtained at the positions noted in Fig 1 with the engine operating at military power. It was occasionally necessary to request the curtailment of some operations in the aircraft testing area when measurements were made forward of the suppressor (Positions 201 through 205).

B. Description of Silencer

Plan and section views of the production silencer are shown in Fig 2. The front of the cell can be opened completely by rolling aside a pair of 10 in. thick poured concrete doors. This permits moving an F-102 or F-106 aircraft into the 76 ft by 46 ft test section. The doors are closed and sealed during engine operation.

Primary air is drawn through four horizontal ducts, two of them located on each side of the enclosure. Each of these ducts contains 16 ft of Soundstream absorbers. The lower duct on each side contains an acoustically lined

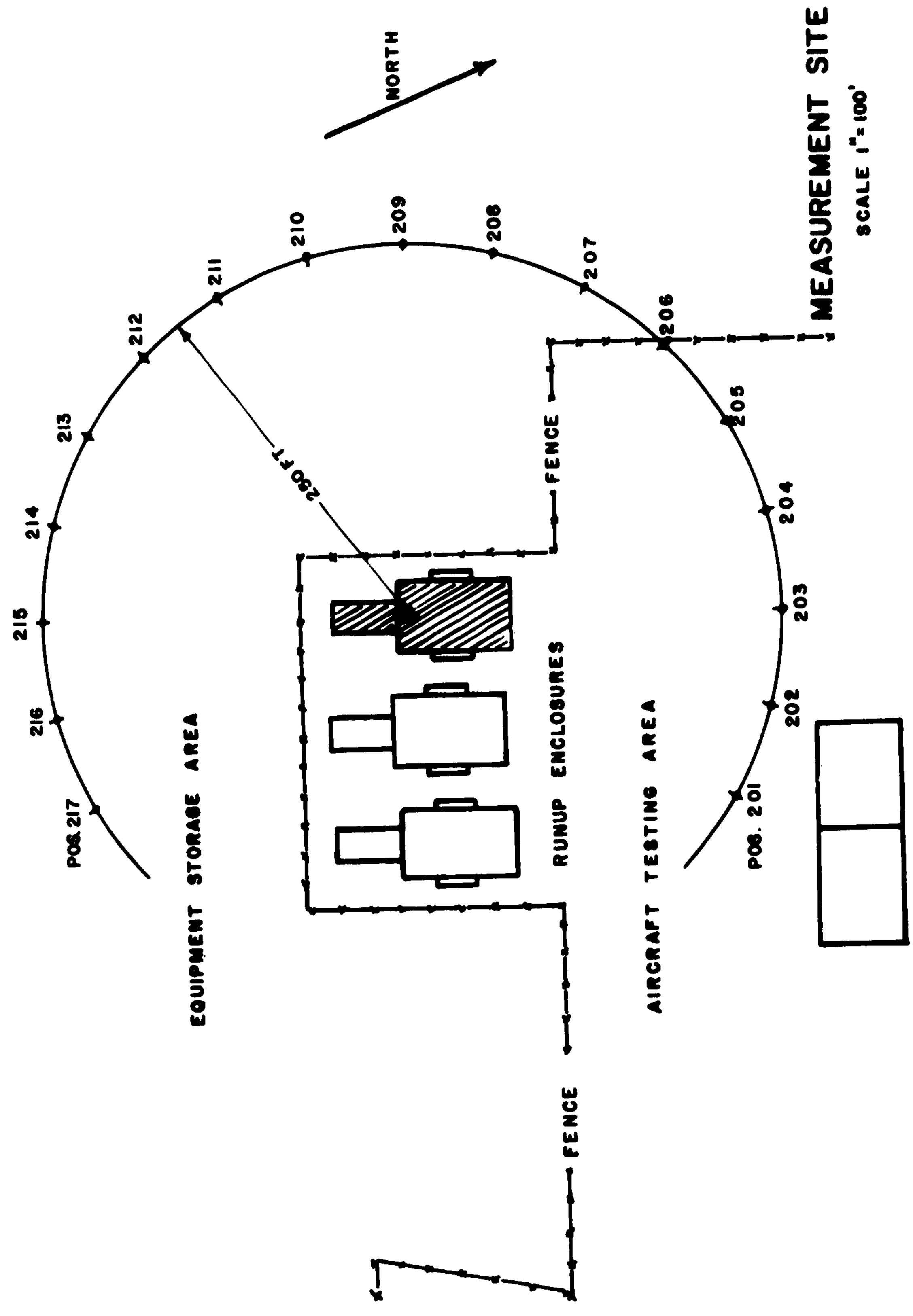

MEASUREMENT SITE
SCALE 1" = 100'
NORTH
250 FT
FENCE
EQUIPMENT STORAGE AREA
RUNUP ENCLOSURES
AIRCRAFT TESTING AREA
POS. 201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
POS. 217
FENCE

FIGURE I

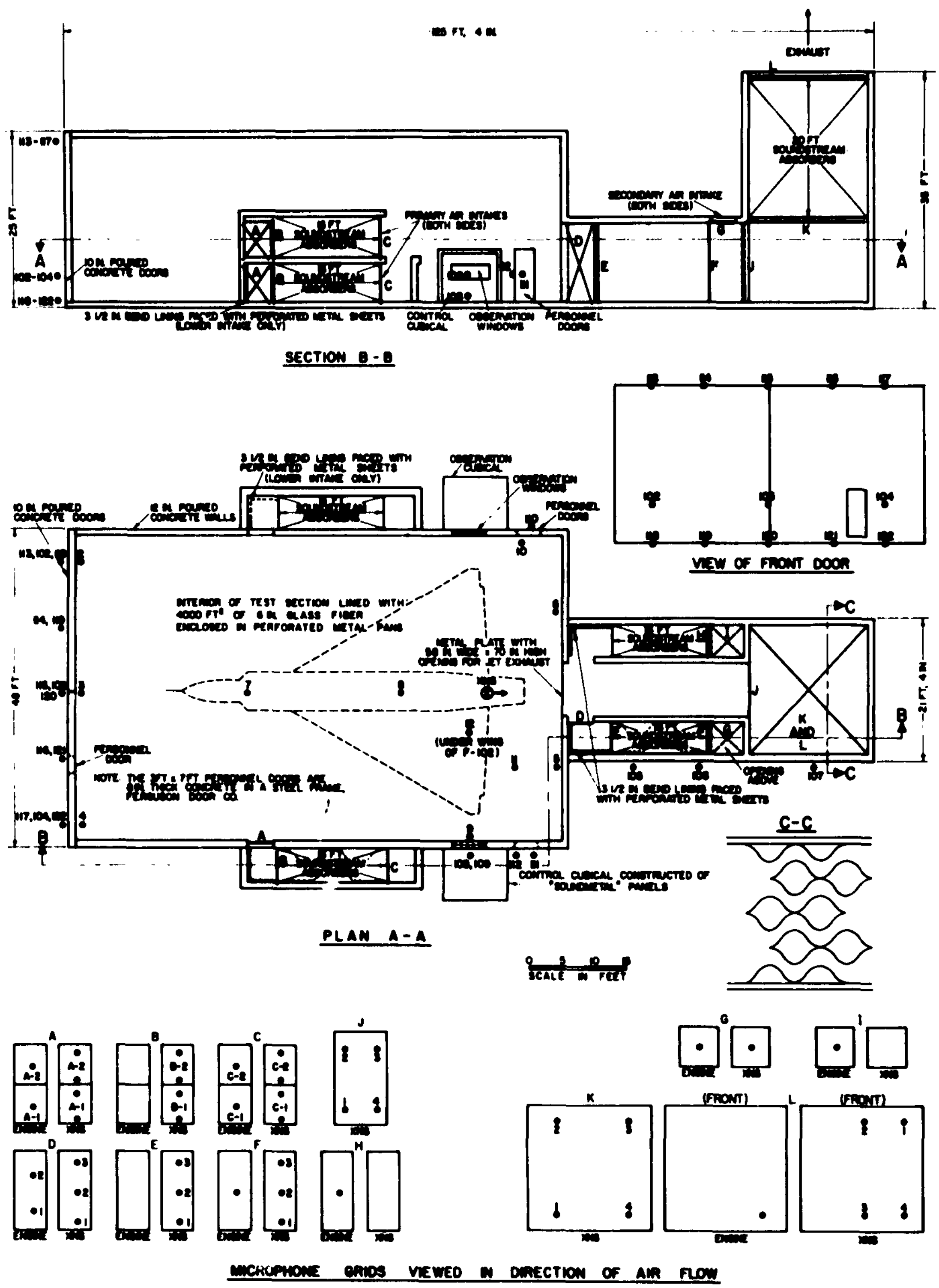


FIG. 2 PLAN AND SECTION VIEWS OF CONVAIR F102 PRODUCTION SILENCER SHOWING MICROPHONE POSITIONS.

bend with a 3-1/2 in. thick lining between the Soundstream absorbers and the test section. No such lining has been placed in the upper ducts. A small vertical wall is located parallel to and a few feet away from the entrance plane of the lower intake on each side. When the upper intake duct on each side was added, evidently at a later date, this wall was not extended upwards. The wall is joined to the concrete slab separating the upper and lower intake ducts by a concrete beam approximately one foot square.

Secondary air is drawn through two ducts, one located on each side of the waterspray chamber in the exhaust section. Each of these ducts contains 16 ft of Soundstream absorbers and a 3-1/2 in. thick lining on the bend at the inside end. The exhaust gases are carried out between the two secondary air intake ducts and up through a vertical stack. This stack contains 20 ft of Soundstream absorbers. Parts of the interior of the test section are lined with a total of 4000 sq ft of 6 in. thick Koppers Company "Soundmetal" panels containing glass fiber material.

Two small control cubicles are located just outside the primary air intakes on each side of the enclosure. However, the engine is run during test by a mechanic in the cockpit of the aircraft, and there are generally at least two other men within the enclosure during an aircraft run-up. All of these men wear headphones for communication and ear protection.

A temperature controlled waterspray system is employed in the exhaust duct. When the control temperature was exceeded, this water spray came on; however, the water flow rate was not measured, and the acoustical measurements were halted at these times.

SECTION III

EQUIPMENT AND MEASUREMENT PROCEDURE

The measurement procedures followed have been discussed in detail previously[1] and it will suffice here to mention briefly some of the techniques used in the field.

In order to evaluate the noise reduction of various acoustical treatments, sound pressure levels (SPL's) were measured with the microphones placed in "grid" planes at the entrances and exits of the individual acoustical treatments. These grids are indicated on Fig 2. When more than one microphone was placed in a grid, the measured SPL's were averaged for the grid. Similarly, microphones were placed on both sides of various doors, windows, and walls, as indicated on Fig 2, in order to determine the noise reduction of these components of the structure.

Other microphone positions were chosen to determine the SPL's in different work spaces and to permit the evaluation of the effects of flanking through door seals, open conduits, etc. A microphone was also placed next to the shoulder of the engine operator in the F-102A aircraft in order to determine the SPL in the cockpit.

Many of the measurements used for determining noise reduction were performed both with an explosive noise source (XNS)* and with the jet engine as a noise source. The

---

* A small cannon which fires a blank 10 gauge shotgun shell.[2]

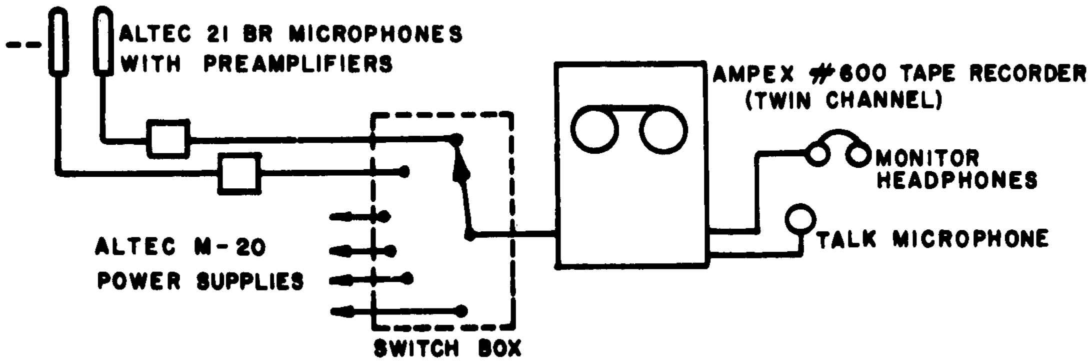
majority of the latter were repeated with the engine operating at idle, 83% rpm, military, and at afterburner power.

Finally, a series of measurements were performed in and around the enclosure with the engine operating at military power in order to determine the contributions from various sources to the SPL measured at 250 ft from the cell.

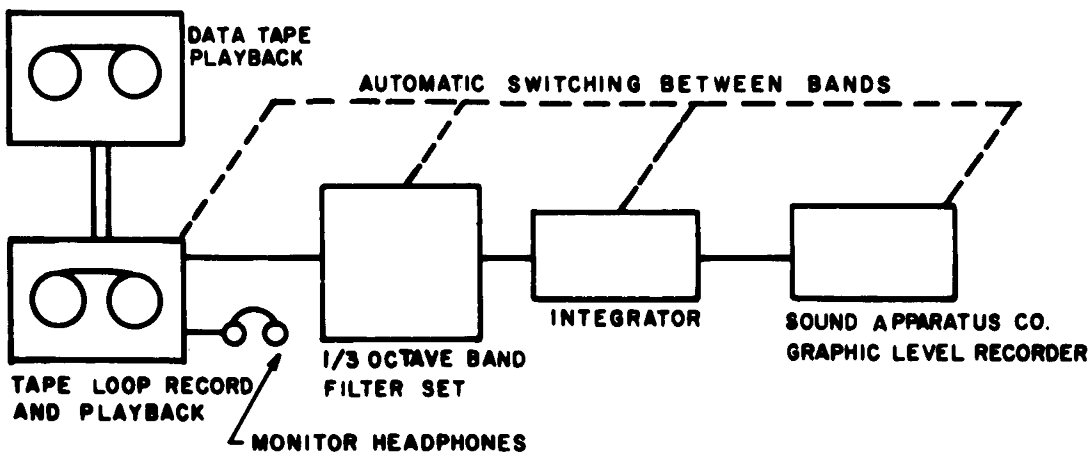
All acoustical data were recorded on magnetic tape using the twin channel system indicated on Fig 3. Unless otherwise noted on Fig 2, the individual measurement positions were located four to five feet above the ground.

To insure accuracy of the equipment during the survey, the measuring system was acoustically calibrated frequently during the time when data were taken.

The data recorded in the field were subsequently reproduced and analyzed in one-third octave bands in the laboratory using the Automatic Data Reduction System (ADRS) indicated schematically on Fig 3. The ADRS has been described in detail previously.[3]



MEASURING SYSTEM



DATA REDUCTION SYSTEM

FIELD RECORDING AND DATA REDUCTION SYSTEMS

FIGURE 3

SECTION IV

SUMMARY OF DATA

A. Acoustical Measurements

All of the measurements obtained during the acoustical survey are listed in Table I. These include: 1) measurements every 15° on a circle 250 ft from the center of the cell; 2) measurements with the explosive noise source at all grids on the west side and exhaust end of the silencer, as well as at positions within the enclosure, outside the doors, and inside the F-102A cockpit; 3) measurements of SPL during engine operation at several operating conditions at intake grids, as well as at Position 1 within the cell and inside the F-102A cockpit; and 4) measurements during engine operation at military power at all exterior grids and positions on both sides of the front door.

The basic data are all given in the body of the report or in the Appendix. Data may be located by reference to Table I, as mentioned above. The measurement positions are indicated on Figs 1 and 2.

B. Engine Operating Conditions

The same F-102A aircraft, Serial No. 61356, was used for all engine measurements. It contained a J57-P-23 engine, Serial No. P-608265, which operated at the approximate conditions listed in Table II. These engine operating parameters were obtained from the cockpit instrumentation in the aircraft.

TABLE I

SUMMARY OF DATA INDICATING FIGURE NUMBERS ON WHICH DATA ARE PLOTTED

		Source			
		Engine			
Position	XNS	Idle (53%)	85%	Mil.	A/B
Grid A	A-1,2	A-8,9	A-8,9	A-8,9	A-8,9
Grid B	A-1,2				
Grid C	A-1,2	A-10,11		A-10,11	A-10,11
Grid D	A-3	A-12	A-12	A-12	A-12
Grid E	A-3				
Grid F	A-3	A-13	A-13	A-13	A-13
Grid G	A-3	A-14	A-14	A-14	A-14
Grid H			A-13		
Grid I			A-14		
Grid J, K	A-4				
Grid L	A-4			A-15	
Pos. 1	A-5	16	16	16	16
Pos. 2,3,4	A-6			A-16	
Pos. 5,6,7,8	A-5				
Pos. 9, 10	A-7				
Pos. 11,12				17	
In F-102A Cockpit	A-5			18	
Pos.102,103, 104	A-6			A-16	
Pos.105,106, 107				A-17	
Pos.108				20	
Pos.109	A-7			20	
Pos.110	A-7			A-18	
Pos.111,112				A-18	
Pos.113-122				A-19, A-20	
Pos.201-217				21,22	

TABLE II

APPROXIMATE ENGINE OPERATING CONDITIONS
DURING ACOUSTIC MEASUREMENTS

Engine Operating Condition	Tailpipe Temp. °C	N_2 Compressor % rpm	Pressure Ratio	Fuel Flow lbs/hr
Idle	330	58.7	---	1000
83% rpm	---	83	---	----
Military (Mil)	605	94.2	2.10	7800
Afterburner (A/B)	605	94.2	2.13	----

SECTION V

RESULTS OF ACOUSTICAL MEASUREMENTS

A. Noise Reduction of Air Passages

In conformity with previous usage[1], the noise reduction (L_{nr}) of an acoustical treatment or structure is defined as the difference in the space average SPL's at the entrance and exit planes of the acoustical treatment or structure. Thus, the L_{nr} of the primary air intake is the difference in the space average SPL's measured at Grid A and at Grid C.*

Actually, there is a significant difference in the noise reduction of the upper and lower halves of the primary air intakes. This results from the difference in configuration which has already been mentioned. The L_{nr} of the upper half, as measured with the XNS, is indicated on Fig 4. Note that the L_{nr} of the unlined bend (Grid B-2 less Grid A-2) is quite small, and that the majority of the total L_{nr}, as measured from Grid A-2 to Grid C-2, is due to the Soundstream absorbers between Grids B-2 and C-2. Similar measurements for the lower half of the intake are indicated on Fig 5. Here it is seen that the lined bend between Grids A-1 and B-1 has a somewhat greater L_{nr} than was measured for the corresponding bend in the upper half of the intake. This is reflected in a greater total L_{nr} for the duct between Grids A-1 and C-1, particularly at the higher frequencies.

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* As defined here, L_{nr} includes the effect of any change in area between grids. Thus, it is not equal to power level reduction.

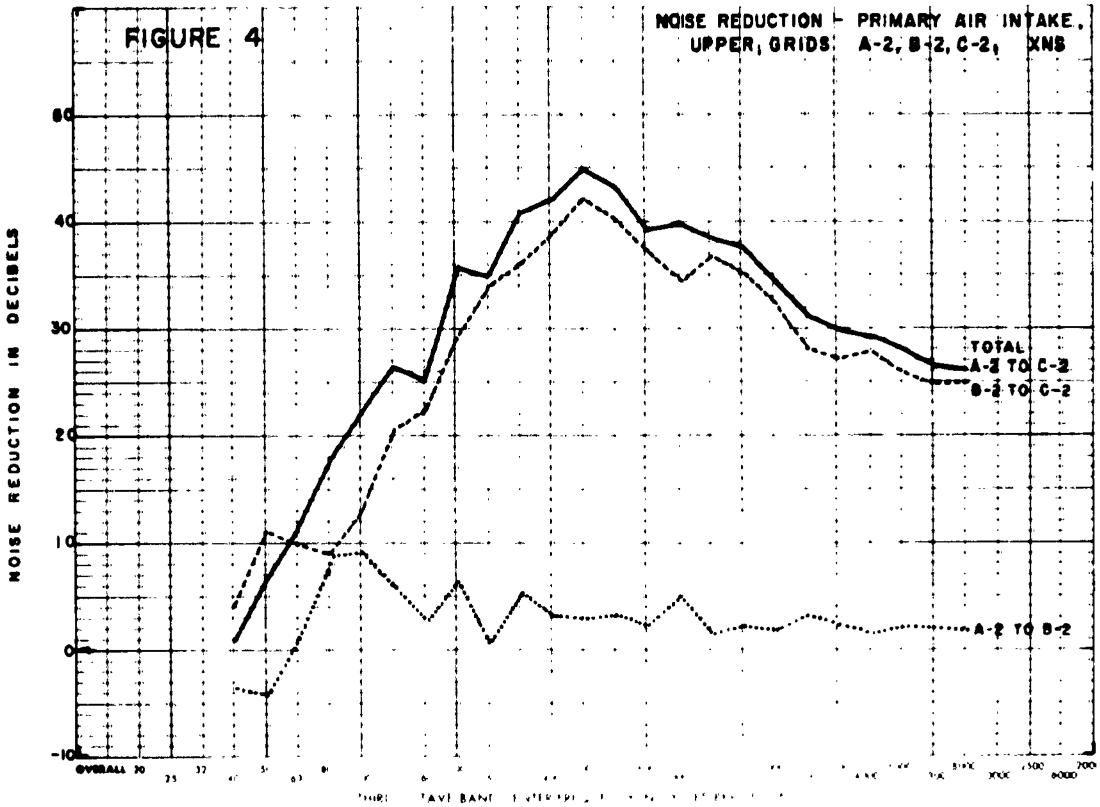
FIGURE 4
NOISE REDUCTION - PRIMARY AIR INTAKE, UPPER GRIDS: A-2, B-2, C-2, XNS
NOISE REDUCTION IN DECIBELS
TOTAL
A-2 TO C-2
B-2 TO C-2
A-2 TO B-2
OVERALL

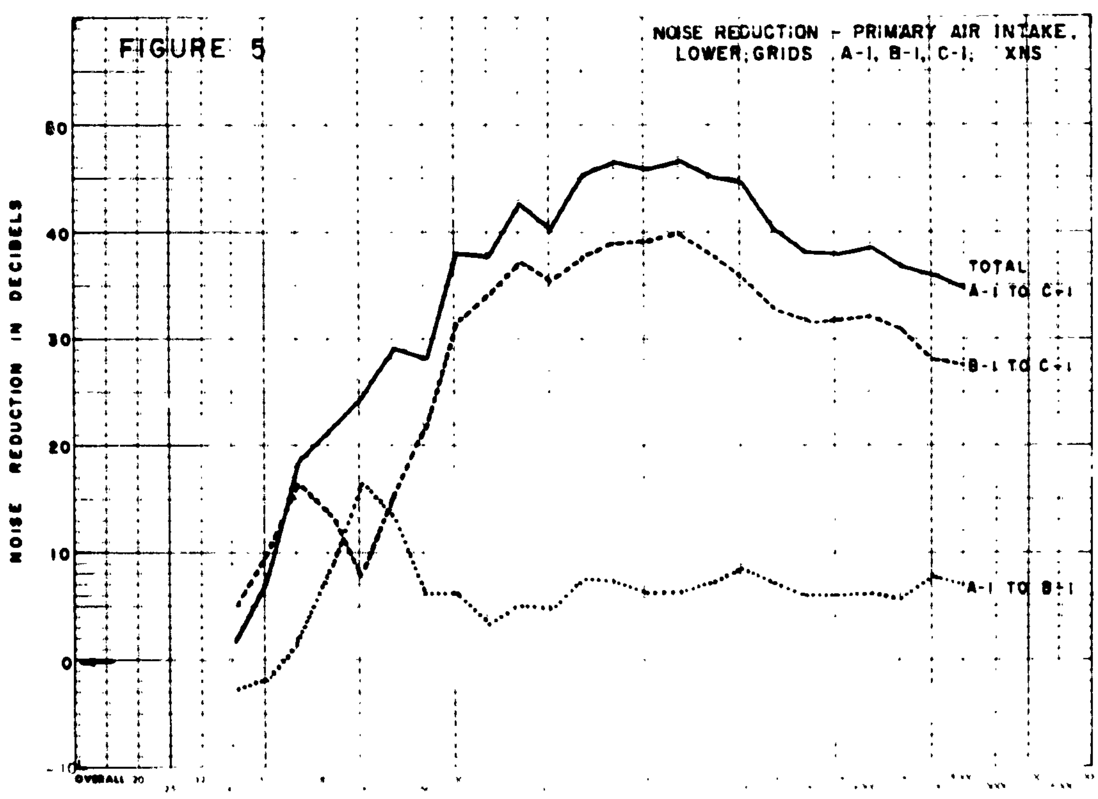
FIGURE 5
NOISE REDUCTION - PRIMARY AIR INTAKE, LOWER GRIDS A-1, B-1, C-1, XNS
NOISE REDUCTION IN DECIBELS
TOTAL
A-1 TO C-1
B-1 TO C-1
A-1 TO B-1
OVERALL

The total L_{nr} for the upper and lower halves of the primary air intake treatment was determined at various engine settings. These data are plotted on Figs 6 and 7. Note that for the three engine power settings, idle, military, and A/B, the L_{nr} curves generally agree within about 5 db. However, the L_{nr} determined from the XNS measurements, which is compared with the engine measurements in both cases, is lower than that obtained during the engine measurements below about 160 cps and above about 2,000 cps. This difference, which has often been encountered in turbojet engine test cell measurements, is generally attributed to the effect of the air flow through the treatment during engine operation.*

The L_{nr} of the secondary air intake determined from XNS measurements is indicated on Fig 8. Here, again, the difference between the lined bend (Grids D and E) and the unlined bend (Grids F and G) is evident. Similar measurements of the total L_{nr} with the engine as a noise source are plotted on Fig 9. Comparison with the XNS measurement, which is replotted on Fig 9, reveals that the L_{nr} during engine operation is almost 10 db greater above 320 cps. However, the XNS measurement agrees most closely with the L_{nr} determined with the engine at idle when the air flow was presumably at a minimum.

Noting that both the upper and lower primary air intakes and the secondary air intake contain 16 ft of Soundstream absorbers, it is interesting to compare the XNS measurements

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* This effect has recently been studied in some detail. See Refs 4 and 5.

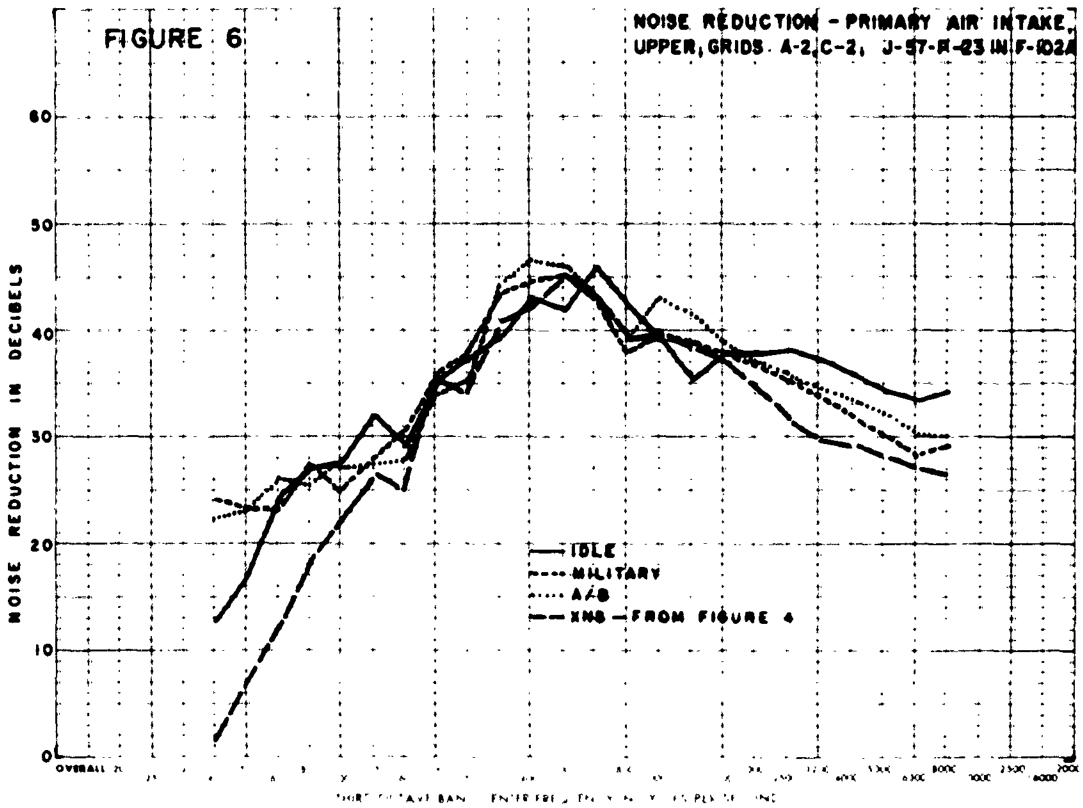

FIGURE 6
NOISE REDUCTION - PRIMARY AIR INTAKE, UPPER, GRIDS A-2, C-2, J-57-P-23 IN F-102A
NOISE REDUCTION IN DECIBELS
0
10
20
30
40
50
60
OVERALL
IDLE
MILITARY
A/B
XNS - FROM FIGURE 4

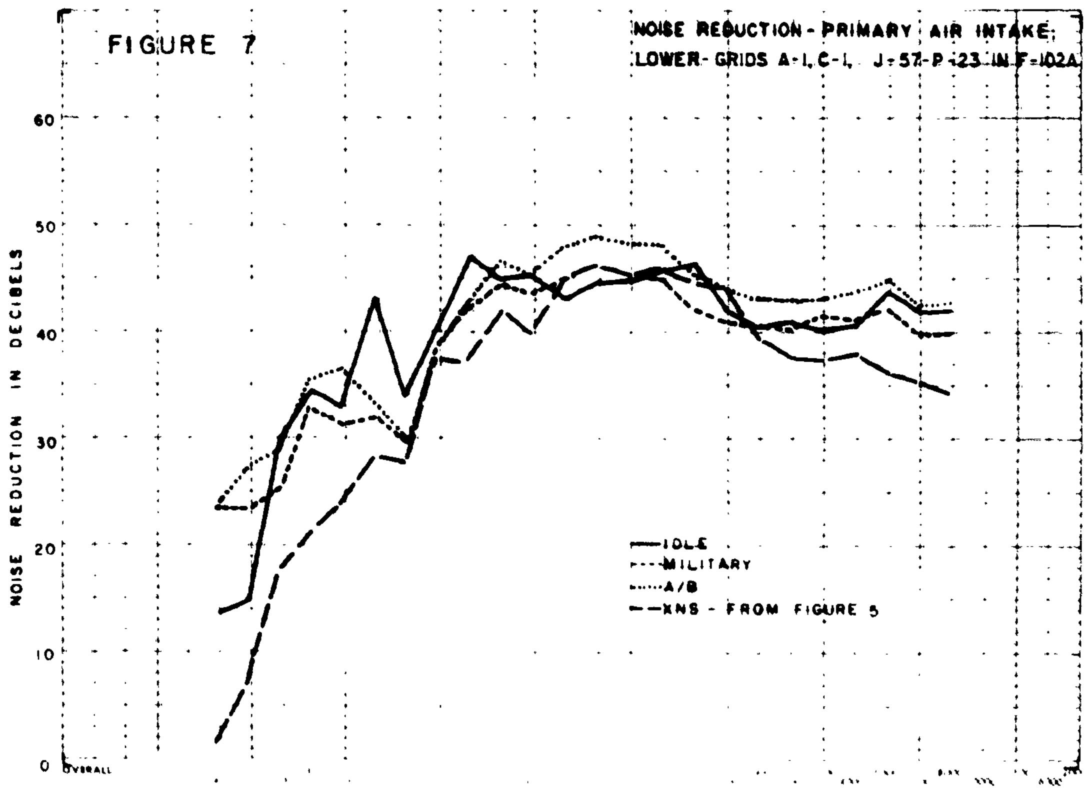

FIGURE 7
NOISE REDUCTION - PRIMARY AIR INTAKE; LOWER- GRIDS A-1, C-1, J-57-P-23 IN F-102A
NOISE REDUCTION IN DECIBELS
0
10
20
30
40
50
60
OVERALL
IDLE
MILITARY
A/B
XNS - FROM FIGURE 5

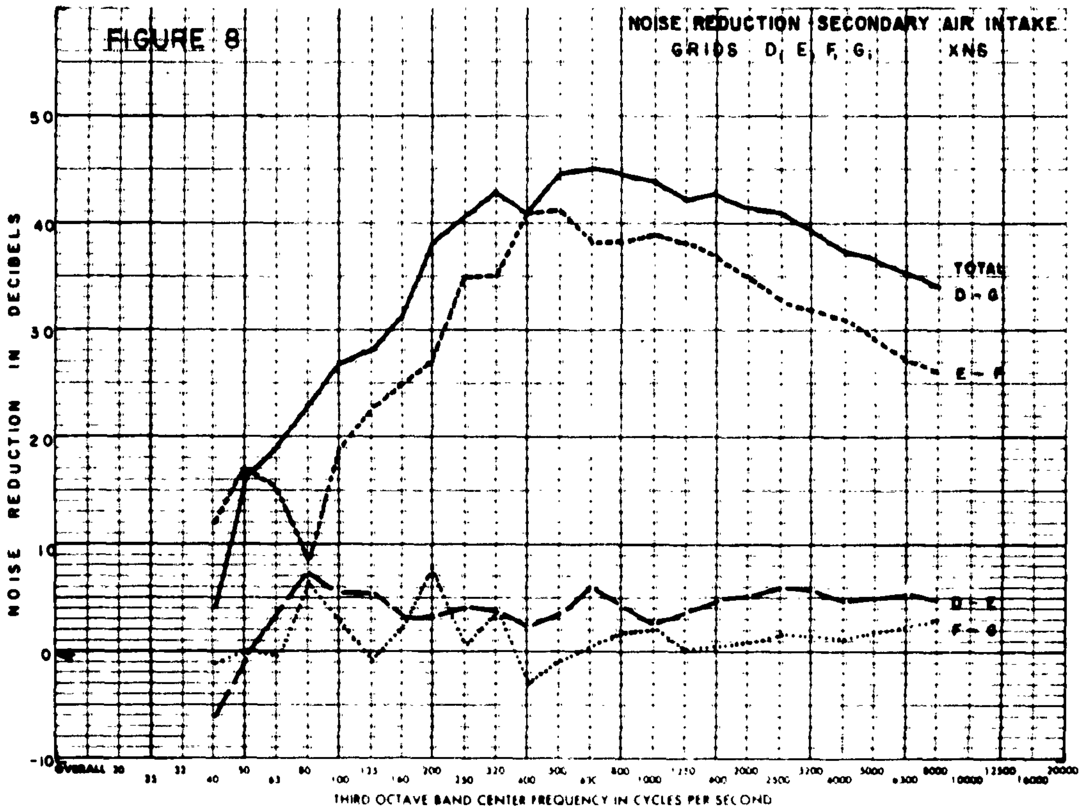
FIGURE 8
NOISE REDUCTION SECONDARY AIR INTAKE
GRIDS D, E, F, G, XNS
NOISE REDUCTION IN DECIBELS
TOTAL
D - G
E - F
D - E
F - G
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

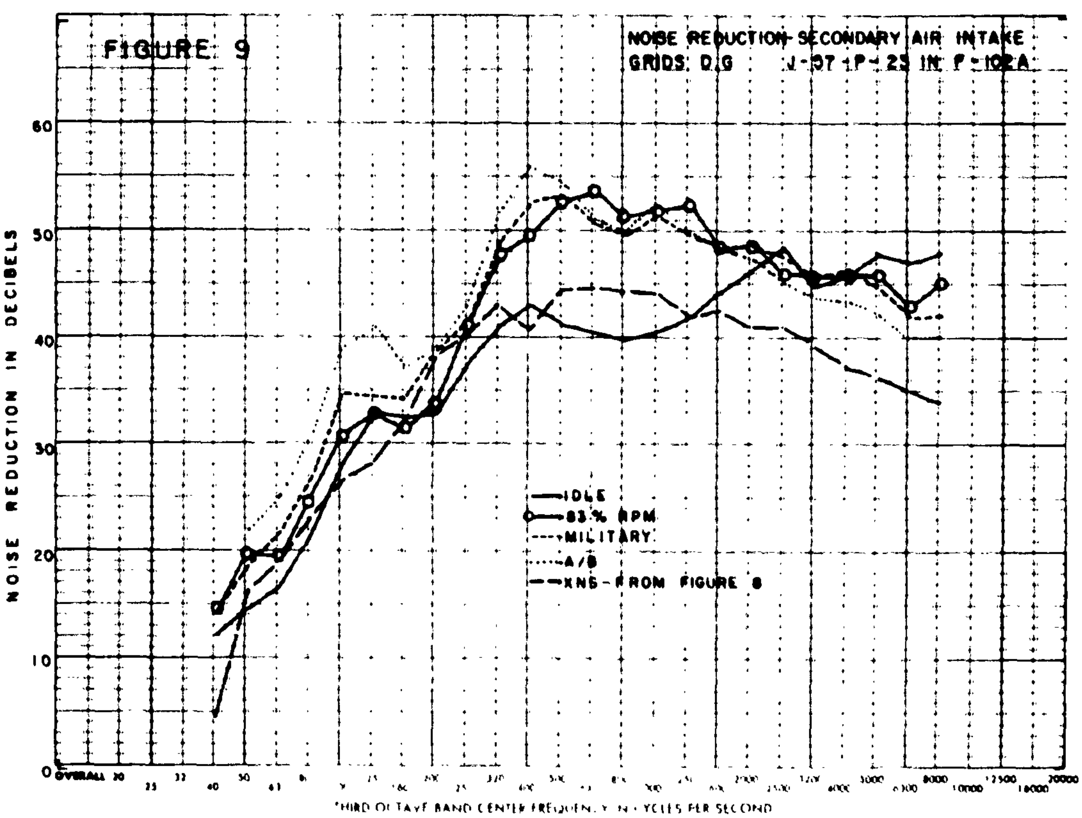
FIGURE 9
NOISE REDUCTION SECONDARY AIR INTAKE
GRIDS D,G J-57-P-23 IN F-102A
NOISE REDUCTION IN DECIBELS
IDLE
83 % RPM
MILITARY
A/B
XNS - FROM FIGURE 8

in the three cases. This comparison is shown in Fig 10, and it is evident that the agreement is generally within about 3 db above 100 cps. The disparity at low frequencies may be due to standing wave patterns in the ducts.

The noise reduction of the various components of the exhaust as measured with the XNS are plotted on Fig 11. It is evident that most of the attenuation is due to the Soundstream absorbers, with some contribution from the unlined bend, particularly below 200 cps.

B. Noise Reduction of Doors and Walls

The L_{nr} of the front door, as determined from the difference in the measured SPL's at Positions 2, 3, 4 inside, and Positions 102, 103, 104 outside, is plotted on Fig 12 for the XNS and Fig 13 for the engine as a noise source. The L_{nr}, particularly at the middle and high frequencies, is much less than would be expected by theoretical considerations. This is evidently due to acoustic flanking through the seals around the doors. Note, for instance, that the L_{nr} obtained during engine operation, Fig 13, is somewhat greater than that measured with XNS. This may result from cell depression tending to force the doors against their seals and thus reduce the acoustic flanking. Further evidence of flanking through door seals is found in the measurements at Positions 113 through 122 (Figures A-19 and A-20) around the exterior of the doors. The noise levels at Positions 114 and 120 are significantly above those at the other positions, indicating leaks through the seals in the vicinity of these high levels.

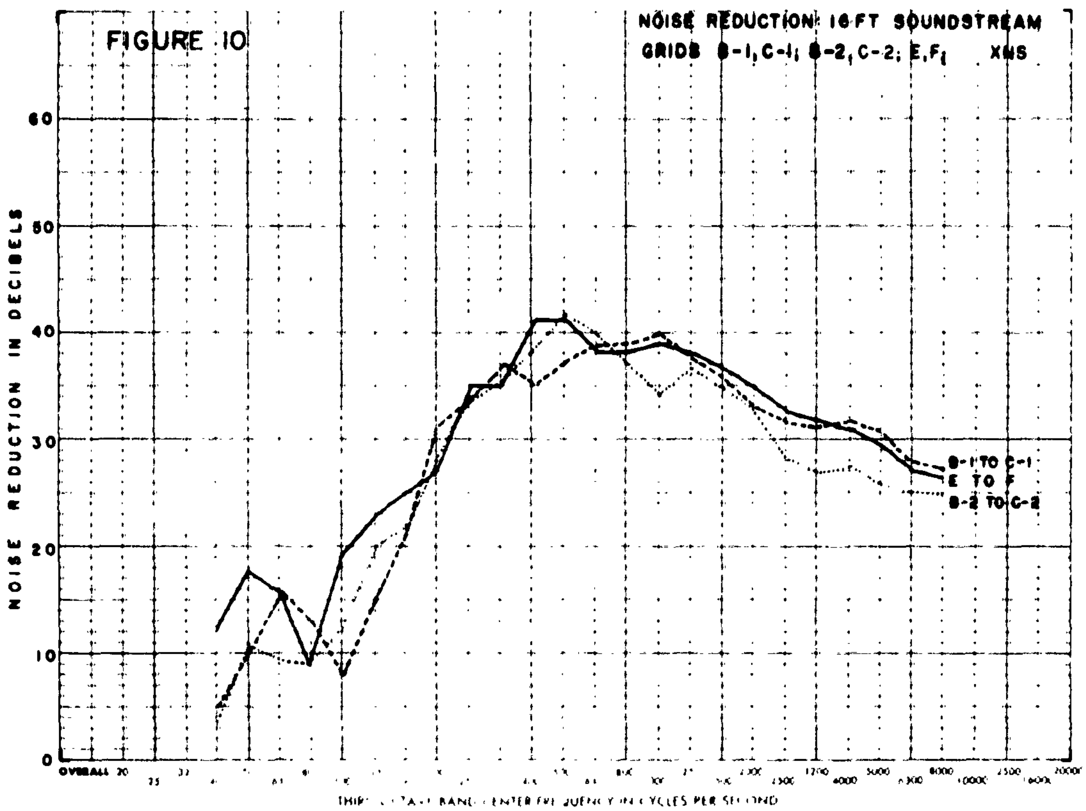
FIGURE 10
NOISE REDUCTION 16 FT SOUNDSTREAM
GRIDS B-1, C-1; B-2, C-2; E, F; XNS
NOISE REDUCTION IN DECIBELS
B-1 TO C-1
E TO F
B-2 TO C-2

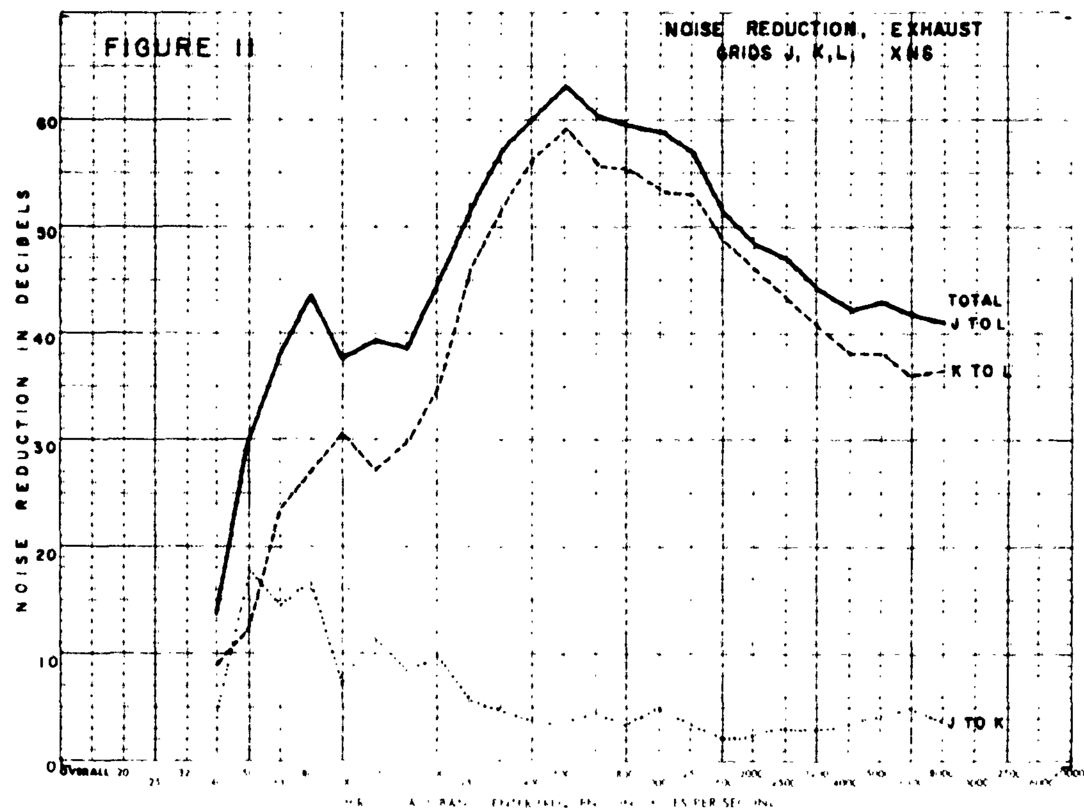
FIGURE 11
NOISE REDUCTION, EXHAUST
GRIDS J, K, L; XNS
NOISE REDUCTION IN DECIBELS
TOTAL
J TO L
K TO L
J TO K

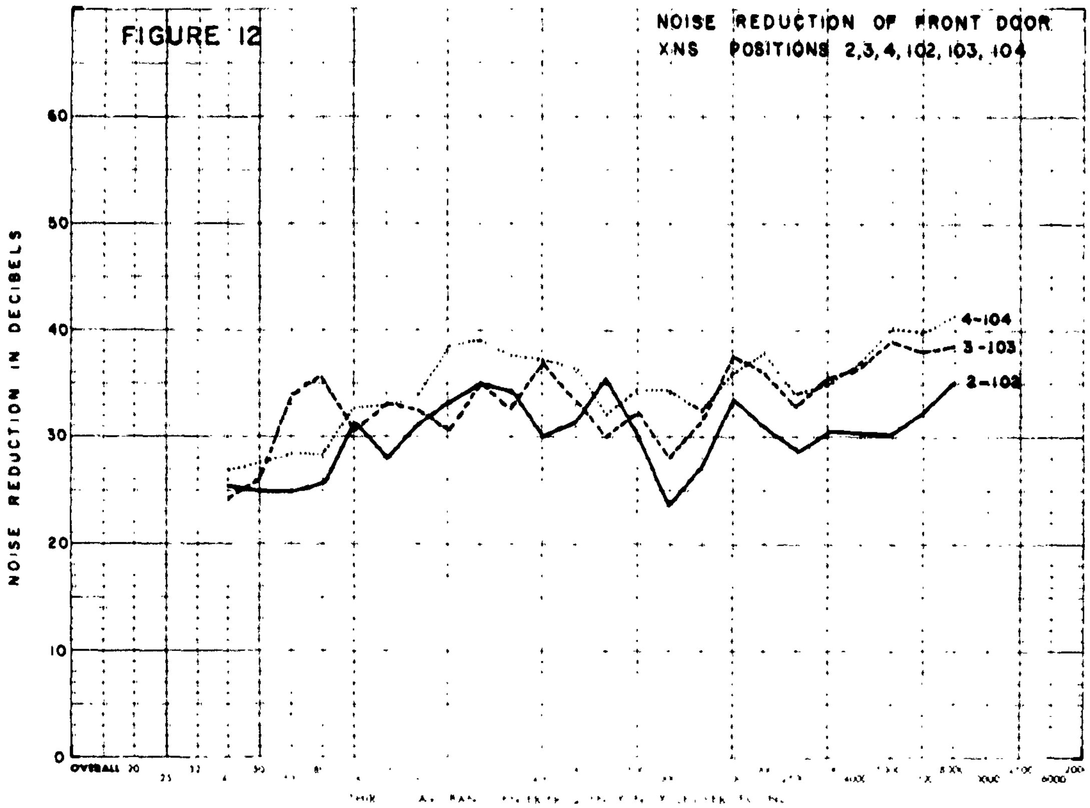
FIGURE 12
NOISE REDUCTION OF FRONT DOOR
XNS POSITIONS 2,3,4,102,103,104
NOISE REDUCTION IN DECIBELS
60
50
40
30
20
10
0
OVERALL
4-104
3-103
2-102

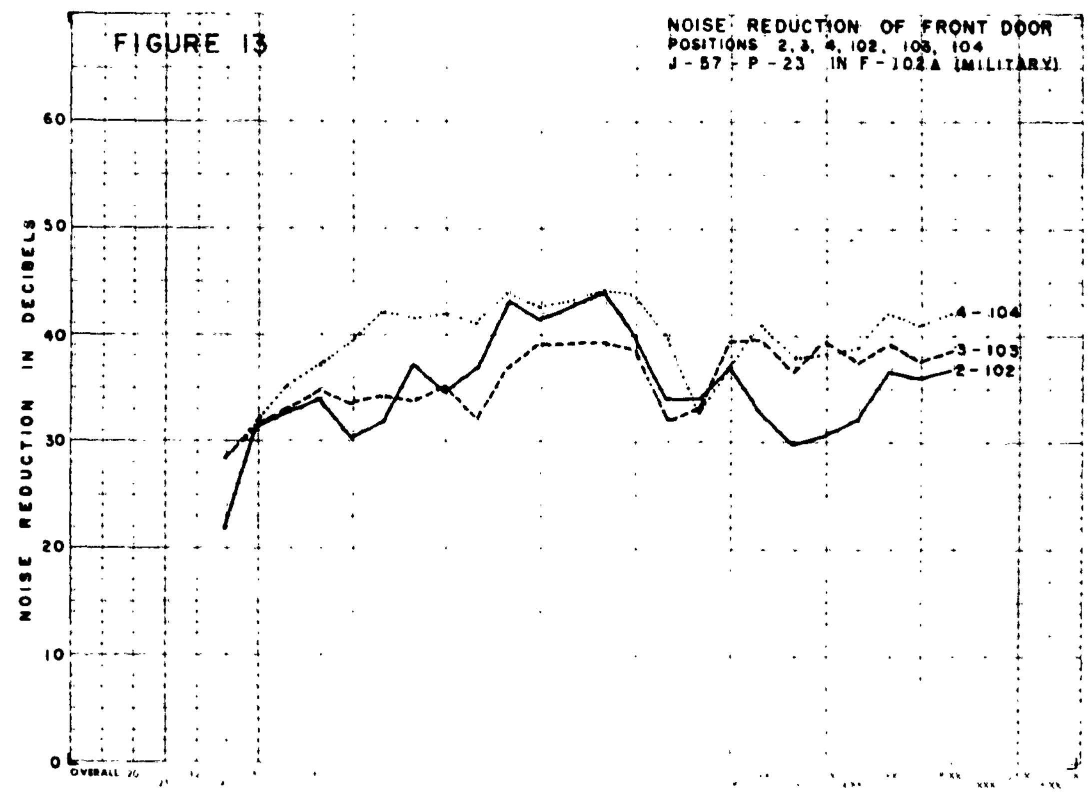
FIGURE 13
NOISE REDUCTION OF FRONT DOOR
POSITIONS 2,3,4,102,103,104
J-57-P-23 IN F-102A (MILITARY)
NOISE REDUCTION IN DECIBELS
60
50
40
30
20
10
0
OVERALL
4-104
3-103
2-102

The L_{nr} of the personnel access door (8 in. thick concrete) on the east side of the enclosure was measured with the XNS and is plotted on Fig 14. In this case, there is a possibility of flanking through the primary air intakes as well as through the seals around the door. Comparing the levels at Grid C-2, Fig A-2, with those at Position 110, Fig A-7, one notes that the SPL due to the XNS at the exit of the upper half of the primary air intake exceeds that at Position 110 by as much as 20 db at very low and very high frequencies. Even when these values are corrected for spherical divergence from the intake to Position 110, they remain high enough to constitute a flanking path.

The L_{nr} of the control cubicle window is plotted on Fig 15. This is probably not a true measure of the noise reduction of the window, however, because of flanking through conduits under the window.

Note, for instance, on Fig 20 that the SPL measured during engine operation at Position 108 is appreciably above that measured at Position 109. Position 108 was located under the bench in the control cubicle just inside, where the conduits pierced the test section wall. The higher SPL measured at this point is a strong indication that a flanking path exists through the conduits.

C. SPL in Work Spaces During Engine Operation

The SPL was measured at various crew locations in the test section during engine operation at idle, 83% rpm, military, and at A/B. The levels measured at Position 1 are plotted

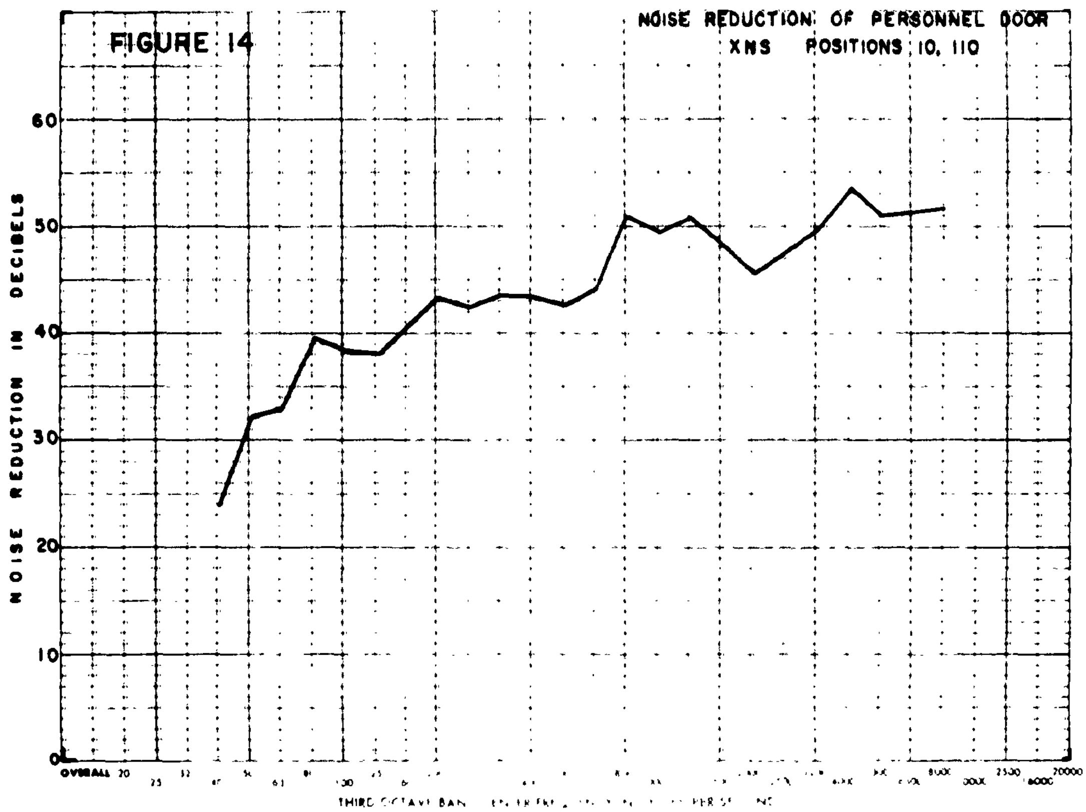
FIGURE 14
NOISE REDUCTION OF PERSONNEL DOOR
XNS POSITIONS 10, 110
NOISE REDUCTION IN DECIBELS
60
50
40
30
20
10
0
OVERALL

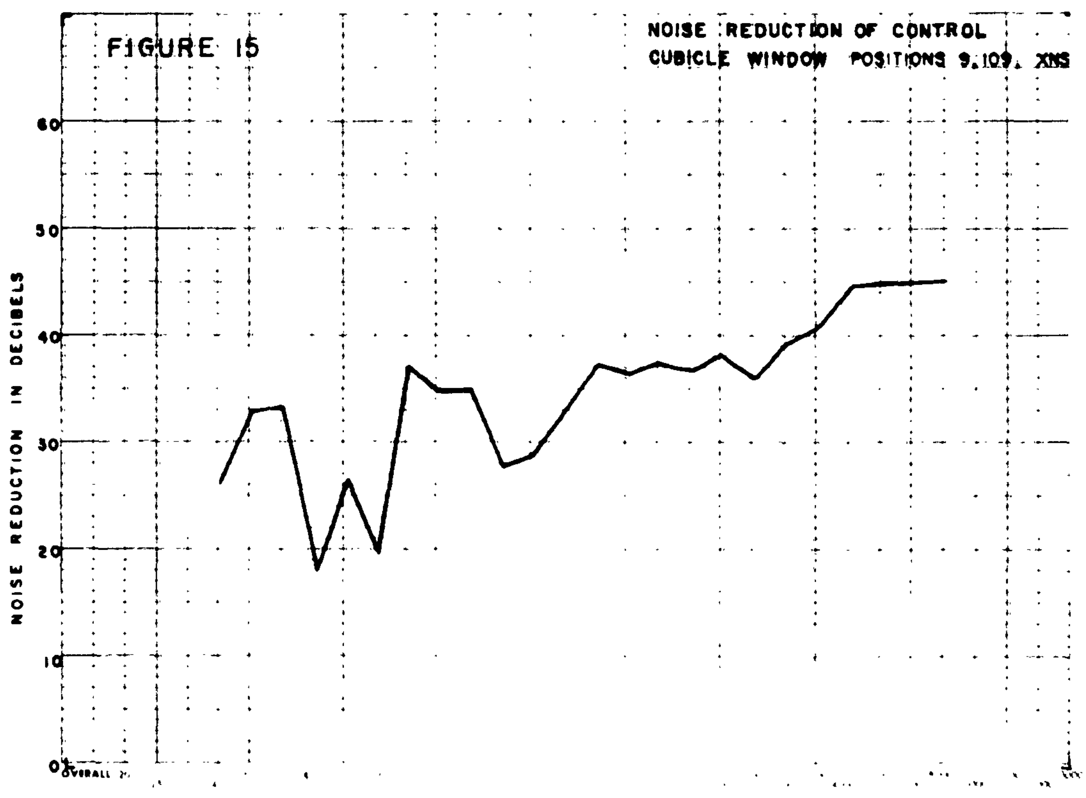
FIGURE 15
NOISE REDUCTION OF CONTROL
CUBICLE WINDOW POSITIONS 9, 109, XNS
NOISE REDUCTION IN DECIBELS
60
50
40
30
20
10
0
OVERALL

on Fig 16. At most power settings, these levels are seen to be well above those considered hazardous for long-time unprotected exposure[6], and are as high as 131 db during A/B operation. As mentioned in Section II-B, all occupants of the test section during engine run-ups wear earphones for communication and ear protection.

With the engine operating at military power, SPL's were also measured at Positions 11 and 12 in the test section. The results of these measurements are plotted on Fig 17, and are seen to be comparable to those at Position 1.

With the engine operating at its military and afterburner power settings, SPL's were measured in the cockpit of the F-102A aircraft near the shoulder of the operator. The levels recorded at this position are plotted on Fig 18. These levels are considerably lower than those observed at Positions 1, 11, and 12 because of the noise reduction of the cockpit canopy. This noise reduction can be approximately determined as the difference between the SPL at Position 1 and that in the cockpit, and is indicated on Fig 19. For comparison, the L_{nr} of the cockpit determined with the XNS is also shown (from Fig A-5). The slightly lower L_{nr} measured at high frequencies during engine operation may be due to sound transmitted from the engine to the cockpit by the structure of the aircraft.

The SPL's measured at Positions 108 and 109 within the control cubicle on the west side of the cell are indicated

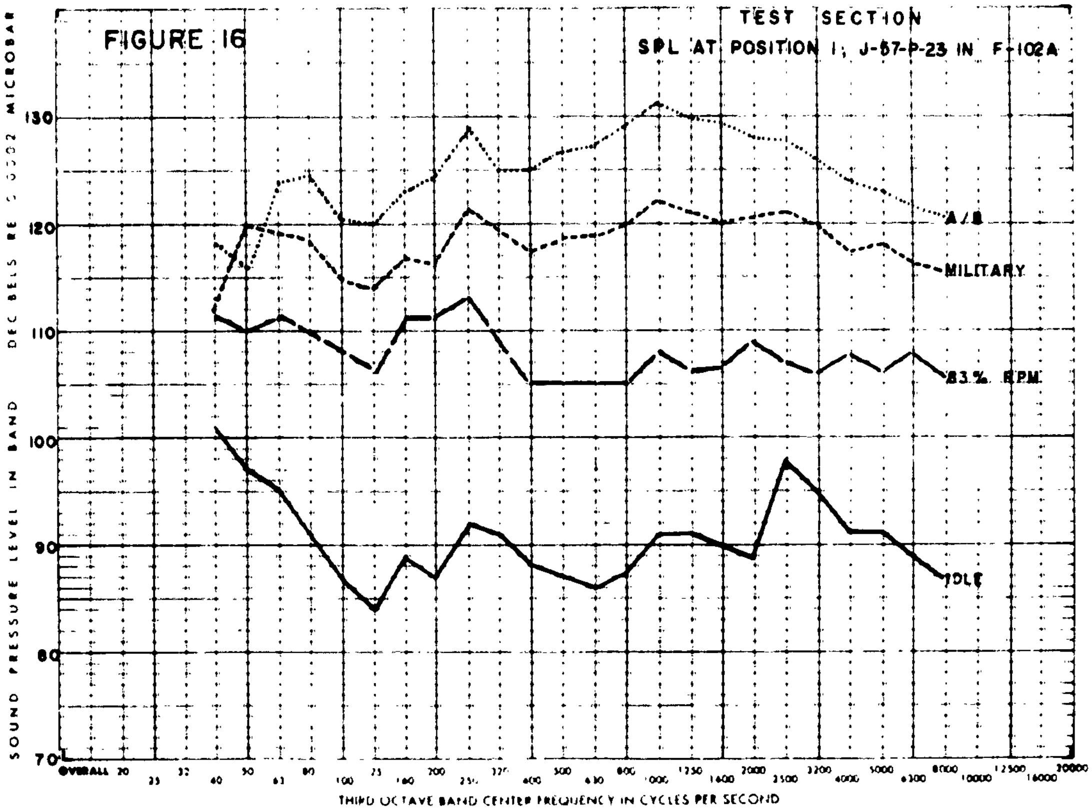

FIGURE 16
TEST SECTION
SPL AT POSITION 1, J-57-P-23 IN F-102A
A/B
MILITARY
83% RPM
IDLE
SOUND PRESSURE LEVEL IN BAND DECIBELS RE 0.0002 MICROBAR
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

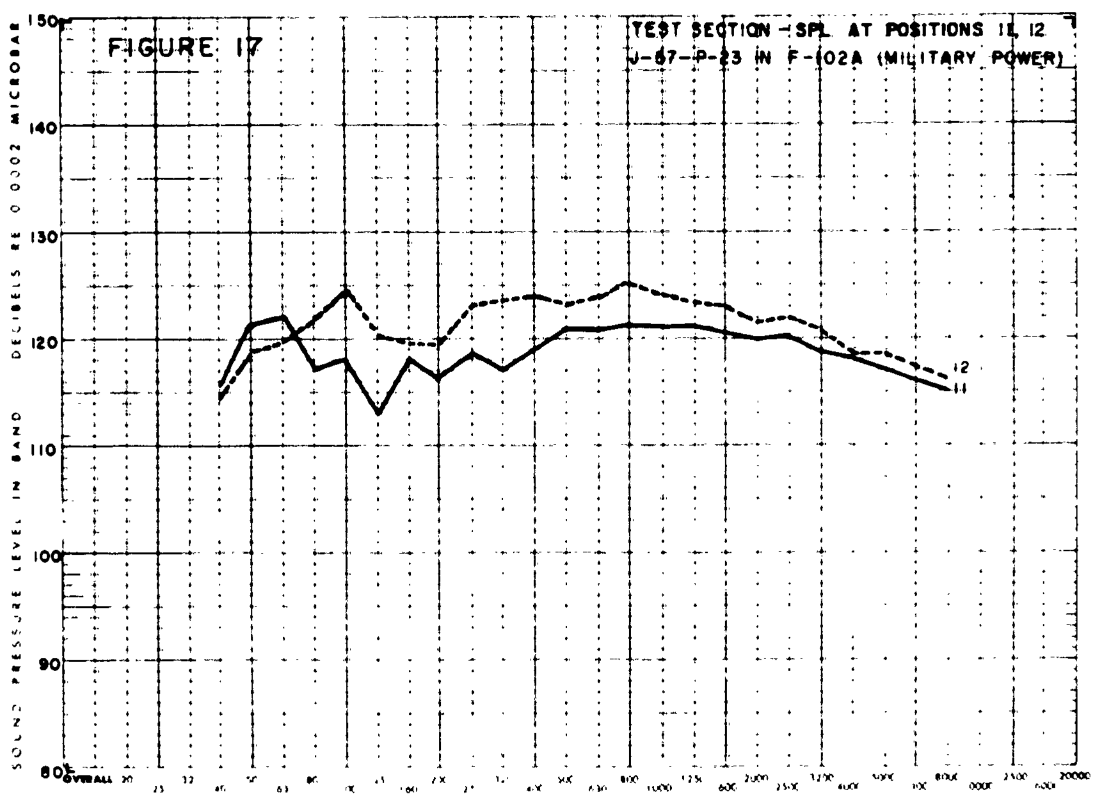

FIGURE 17
TEST SECTION - SPL AT POSITIONS 11, 12
J-57-P-23 IN F-102A (MILITARY POWER)
12
11
SOUND PRESSURE LEVEL IN BAND DECIBELS RE 0.0002 MICROBAR
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

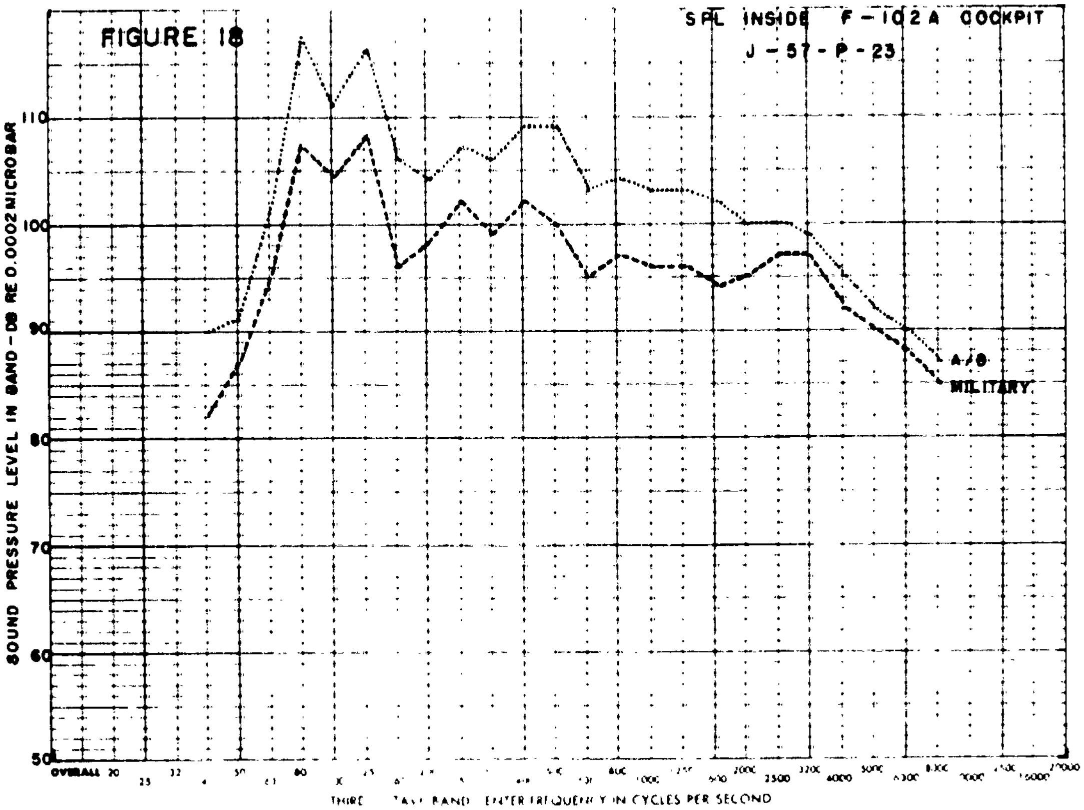
FIGURE 18
SPL INSIDE F-102A COCKPIT
J-57-P-23
SOUND PRESSURE LEVEL IN BAND-DB RE 0.0002 MICROBAR
A/B
MILITARY

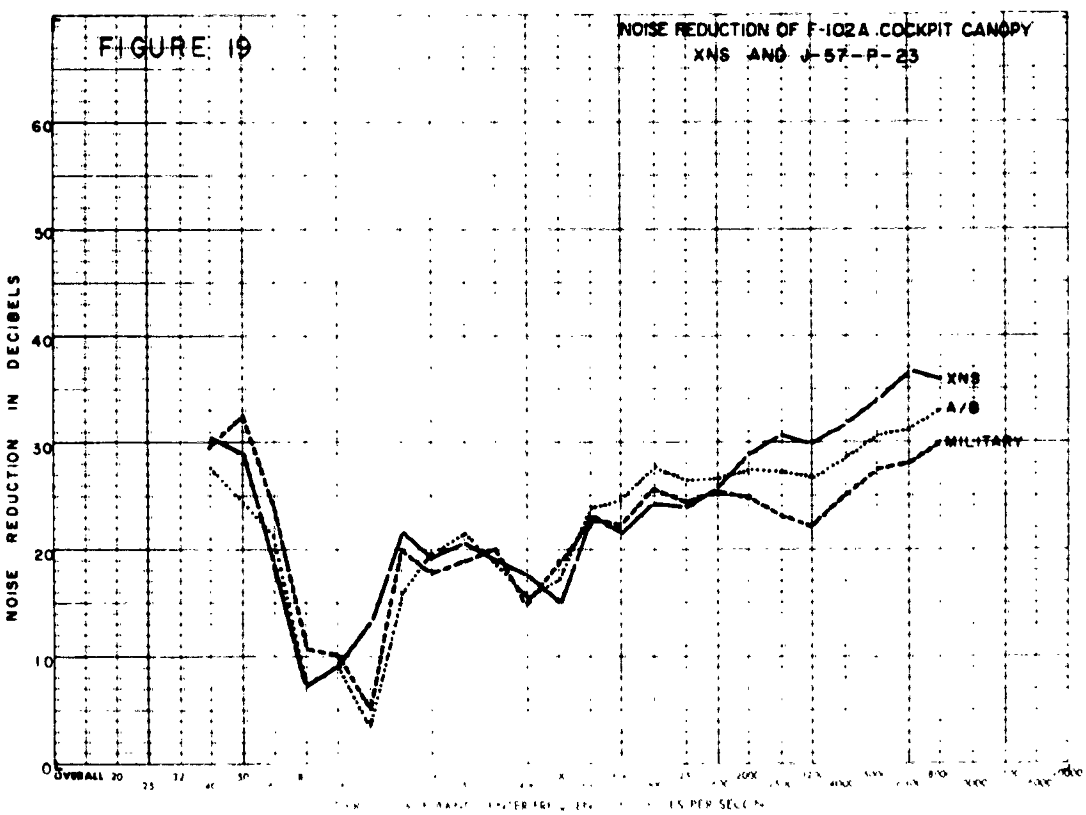
FIGURE 19
NOISE REDUCTION OF F-102A COCKPIT CANOPY
XNS AND J-57-P-23
NOISE REDUCTION IN DECIBELS
XNS
A/B
MILITARY

on Fig 20. The levels near the window (Position 109) are representative of those at the position of the occupants and produce a speech interference level (SIL)[7] of about 70 db. This indicates that occupants of the control cubicle would have to converse by shouting when more than about 2 ft apart in order to be understood. As mentioned above, the noise levels at Position 108 are due to conduits through the cell wall below the window. These openings appear to appreciably reduce the effective noise reduction of the wall between the test section and the control cubicle.

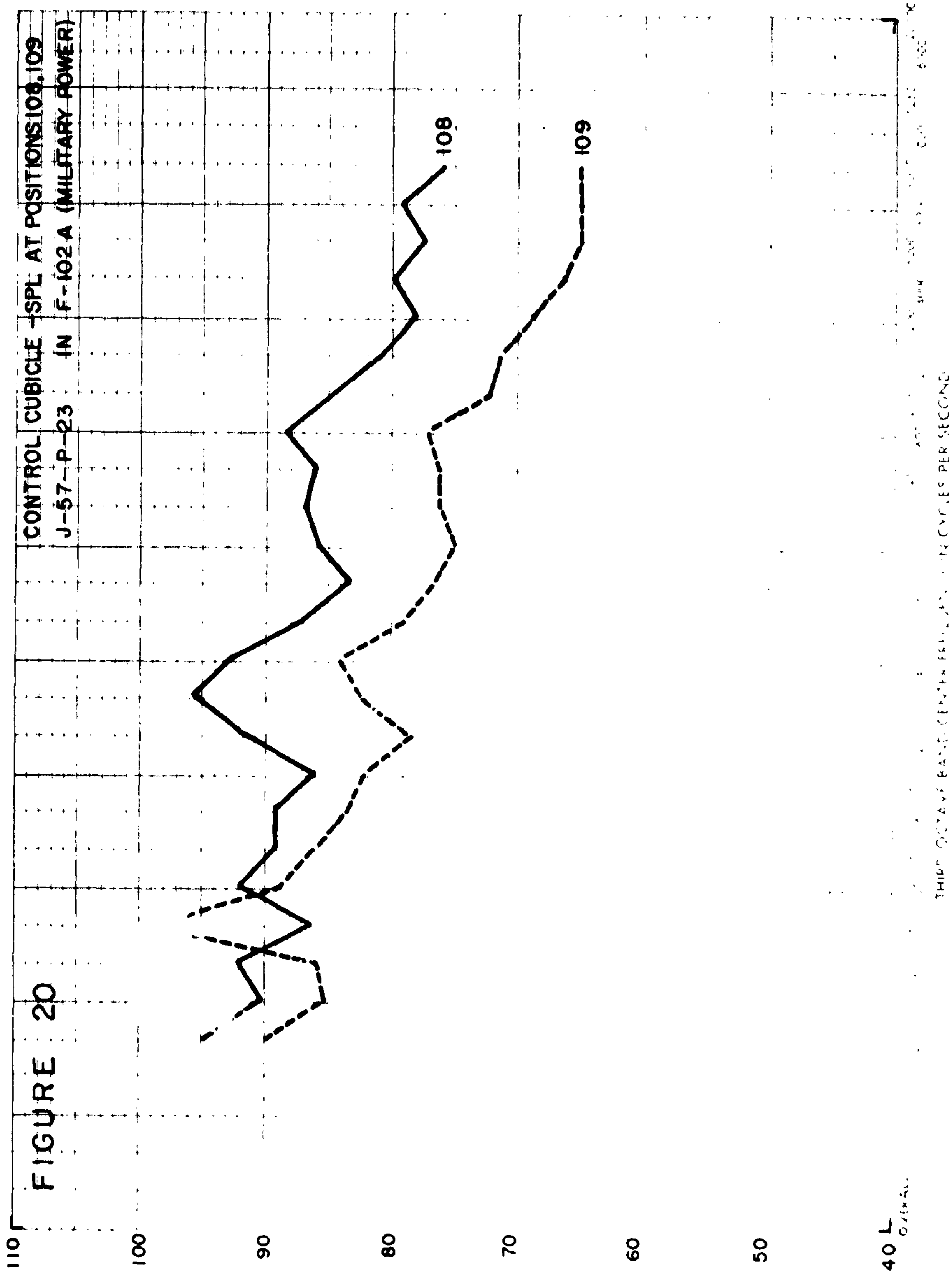
FIGURE 20
CONTROL CUBICLE — SPL AT POSITIONS 108, 109
J-57-P-23 IN F-102A (MILITARY POWER)
108
109
110
100
90
80
70
60
50
40
CYCLES PER SECOND

D. Overall Acoustical Effectiveness of Production Silencer

The results of the distant-field measurements, 250 ft from the cell, are plotted in polar form for each of the eight standard octave bands on Figs 21 and 22. It is interesting to note the peaks in the directivity patterns due to the flanking transmission through the door seals (around 0°), radiation from the primary air intakes (110° to 165°), and the dip due to shielding by the exhaust stack (180°).

The production silencer can be considered as a complex noise source made up of several different noise radiating components. These components include the exhaust openings, the primary and secondary air intake openings, the walls of the silencer, and the various flanking paths through door seals, etc. In order to better understand the acoustical characteristics of the silencer, an analysis has been performed to determine the contribution of the various individual noise sources to the average SPL at 250 ft for engine operation at military power.

Representative measurements of SPL at each of the individual sources were chosen from the data, as indicated on Table III, and, when converted to octave band levels, were used to calculate the contribution of each source to the average SPL's at 250 ft.

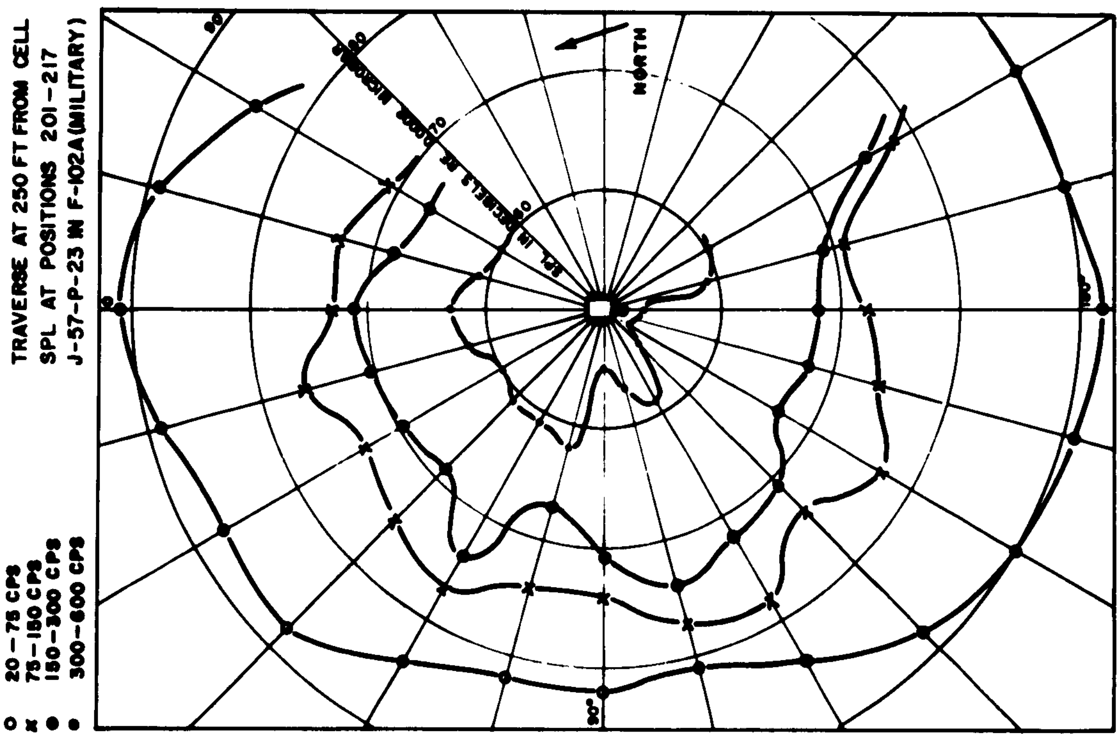

FIGURE 21

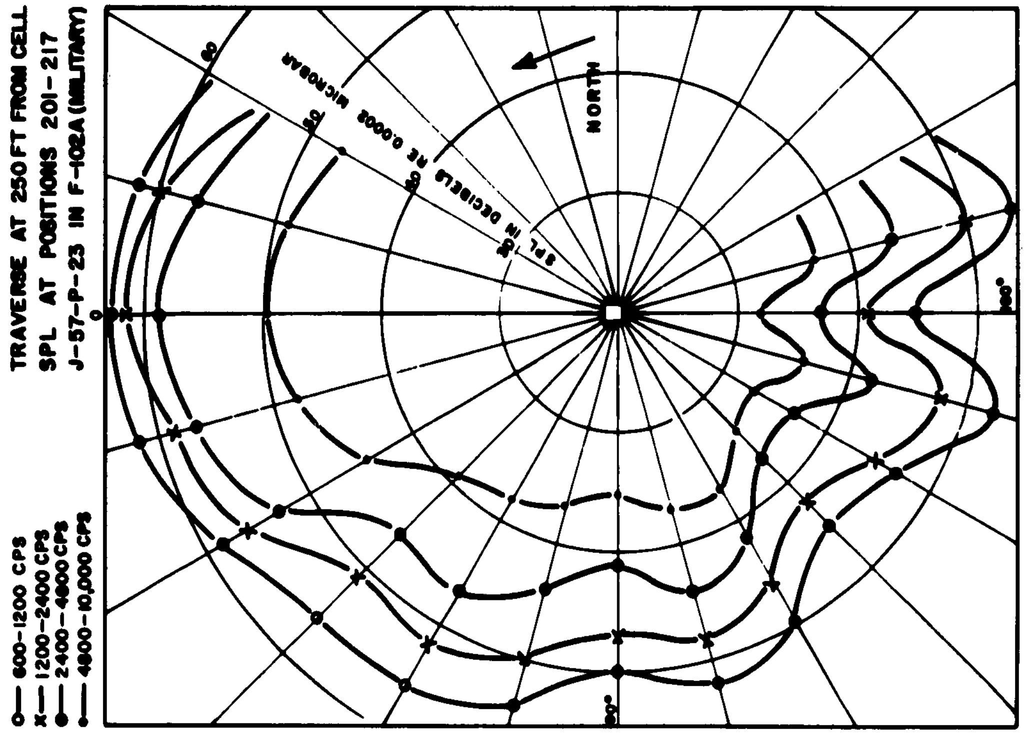

FIGURE 22

TABLE III

OUTLINE OF PROCEDURES USED TO DETERMINE CONTRIBUTIONS FROM VARIOUS SOURCES TO SPL_{avg} AT 250 FT DURING ENGINE OPERATION AT MILITARY POWER

Source	SPL Assumed To Exist Over Source From Fig	Assumed Area of Source	Assumed Directivity of Source
Primary Intake	A-10, A-11	120 ft^2	None*
Secondary Intake	A-14	60 ft^2	Vertical[4, 8]
Exhaust	A-15	400 ft^2	Vertical[4, 8]
Front Door	A-16	1000 ft^2	None*

These calculations were performed by use of the following expression:

$$SPL_{250\ ft} = SPL_{meas.} + 10 \log_{10} A - 10 \log_{10} (2\pi r^2) - V - G$$

where:

$SPL_{250\ ft}$ = the average SPL at 250 ft from the source in question

$SPL_{meas.}$ = the SPL measured at the source

A = the area of the source

r = 250 ft

V = loss in db due to directivity[4,8]

G = attenuation in db due to ground and air absorption[9]

* Actually, these sources will be directive, producing their highest levels along an axis normal to the exit plane of the source. However, these axes are all horizontal, and the directivity effect is assumed to cancel out when averaging SPL's in the horizontal plane.

The results of these calculations, in terms of contributions from the various sources, are plotted on Fig 23. The total estimated SPL at 250 ft has been calculated by summing these individual spectra and is also plotted on Fig 23. Comparison of these estimated noise levels at 250 ft with the measured average SPL at 250 ft indicates that the two are generally within 2 to 4 db except for the first and last bands. The discrepancy in the 20 - 75 cps band is likely due to the fact that the estimated values were derived from one-third octave band data which were taken down to the "40 cps band" only. Since the spectra are sloping upward at the low frequencies, the summing of one-third octave band SPL's to give a 20 - 75 cps reading would be expected to result in a lower value. In the 2nd, 3rd and 4th octave bands the measured values exceed the estimated SPL's very likely because of radiation of sound from the walls and roof of the cell which is rather difficult to calculate. In general, however, the agreement is rather good, and the analysis indicates the relative contributions from the various sources as a function of octave bands.

It is also of interest to compare the measured average SPL's at 250 ft from the suppressor with the average SPL's that would exist 250 ft away from an unenclosed J57 engine operating under the same conditions. This type of comparison permits the calculation of the insertion-loss noise reduction. From measured data[10/] the average sound pressure level spectrum produced at 250 ft from a J-57-P7 engine operating at military power in an F100A aircraft* has been determined. Comparison of the two average SPL spectra results in the insertion-loss NR shown in Fig 24.

---

* It is assumed that no difference in noise radiation would exist between a J-57-P23 engine in an F102A aircraft and a J-57-P7 engine in an F100A aircraft. Experience indicates this assumption to be valid.[11/]

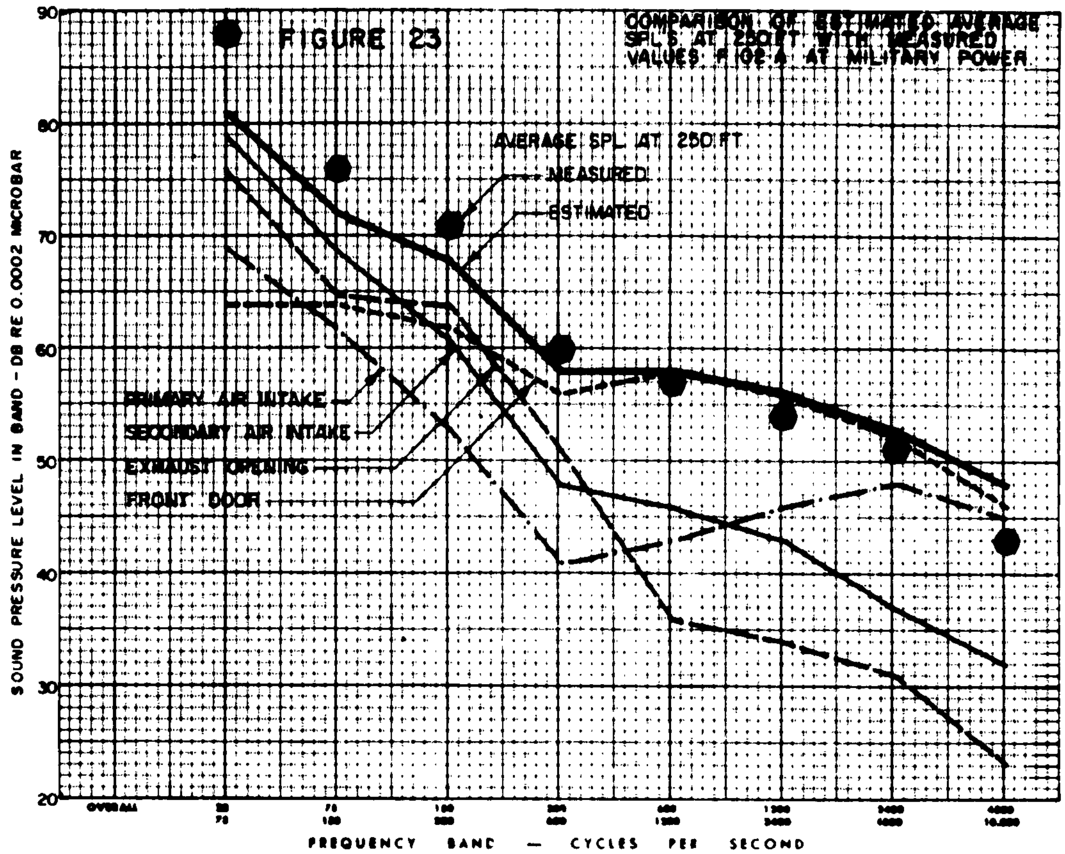
FIGURE 23
COMPARISON OF ESTIMATED AVERAGE SPL'S AT 250 FT WITH MEASURED VALUES F 102-A AT MILITARY POWER
AVERAGE SPL AT 250 FT
MEASURED
ESTIMATED
PRIMARY AIR INTAKE
SECONDARY AIR INTAKE
EXHAUST OPENING
FRONT DOOR
SOUND PRESSURE LEVEL IN BAND - DB RE 0.0002 MICROBAR
FREQUENCY BAND — CYCLES PER SECOND

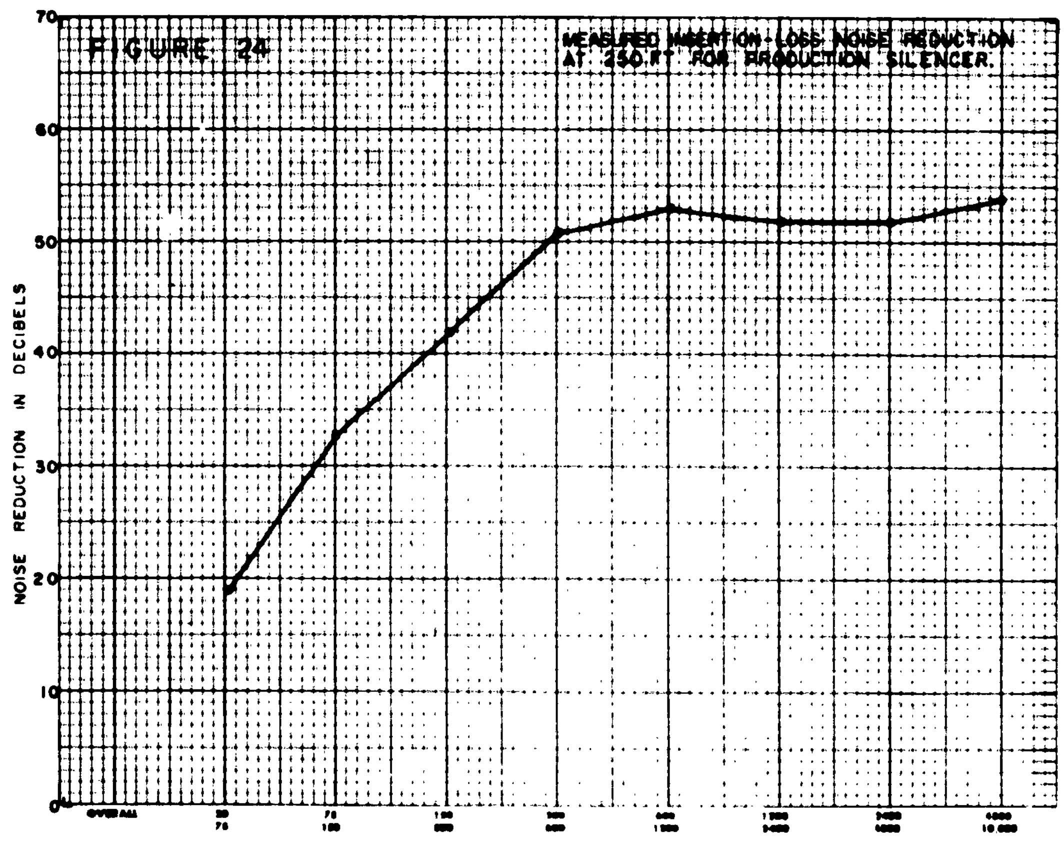
FIGURE 24
MEASURED INSERTION-LOSS NOISE REDUCTION AT 250 FT FOR PRODUCTION SILENCER.
NOISE REDUCTION IN DECIBELS
FREQUENCY BAND — CYCLES PER SECOND

SECTION VI

SUMMARY

The F-102 Production Silencer represents an application of turbojet engine test cell silencing techniques to aircraft ground run-up silencing requirements. As such it is somewhat larger and certainly less portable than those types of ground run-up silencers which connect to, rather than enclose the aircraft.[10,12] However, this is compensated for by the greater noise reduction obtained with a complete enclosure, and by the greater flexibility which permits testing any aircraft which will fit into the enclosure.

This acoustical evaluation of the F-102 production silencer has permitted the determination of the noise reduction of the different acoustical elements of the silencer. These include the walls and doors of the test section and the components of the acoustical treatment in the air intake and exhaust passages. In addition, the evaluation has permitted an approximate determination of the contributions of various sources to the measured noise levels at 250 feet from the silencer. Finally, the insertion-loss noise reduction of the silencer has been determined.

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1. Galloway, W.J., A.C. Pietrasanta, and the Staff of Bolt Beranek and Newman Inc., Procedures for Performing and Evaluating Acoustical Surveys of Turbojet Engine Test Facilities, WADC Technical Report 55-145, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, April 1955.

2. Galloway, W.J., B.G. Watters, and J.J. Baruch, "An Explosive Noise Source," J. Acoust. Soc. Am., Vol 27, pp 220-233, 1955.

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4. Doelling, N., and the Staff of Bolt Beranek and Newman Inc., Noise Control for Aircraft Engine Test Cells and Ground Run-up Suppressors-Volume Three-An Engineering Analysis of Measurement Procedures and of Design Data, WADC Technical Report 58-202(3), Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, November 1961.

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9. Stevens, K.N., A.C. Pietrasanta, and the Staff of Bolt Beranek and Newman, Inc., Procedures for Estimating Noise Exposure and Resulting Community Reaction from Air Base Operations, WADC Technical Note 59-10, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, April 1957.

10. Hoover, R.M., and the Staff of Bolt Beranek and Newman Inc., Acoustical Evaluation of General Sound Control Model N-400 Jet Aircraft Noise Suppressor, WADC Technical Note 57-391, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, April 1958.

11. Doelling, N., D.M.A. Mercer, and the Staff of Bolt Beranek and Newman Inc., A Compilation of Turbojet Noise Data, WADC Technical Report 54-401, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, July 1956.

12. Doelling, N., and the Staff of Bolt Beranek and Newman Inc., An Acoustical Evaluation of Two Durastack Ground Run-up Noise Suppressors, WADC Technical Note 57-392, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, November 1961.

APPENDIX A

MEASURED DATA

In this Appendix are included the basic measured data. For reference to specific data see Table 1 on pg. 12.

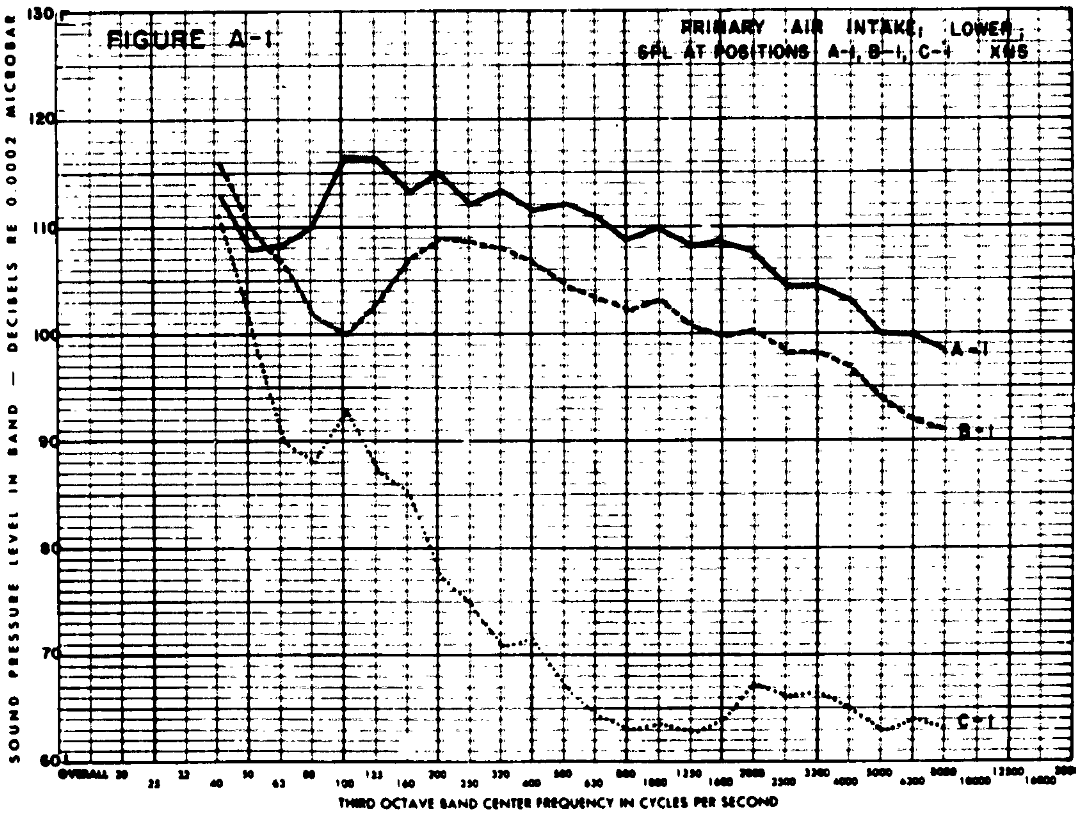
FIGURE A-1
PRIMARY AIR INTAKE, LOWER
SPL AT POSITIONS A-1, B-1, C-1 XMS
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND
A-1
B-1
C-1

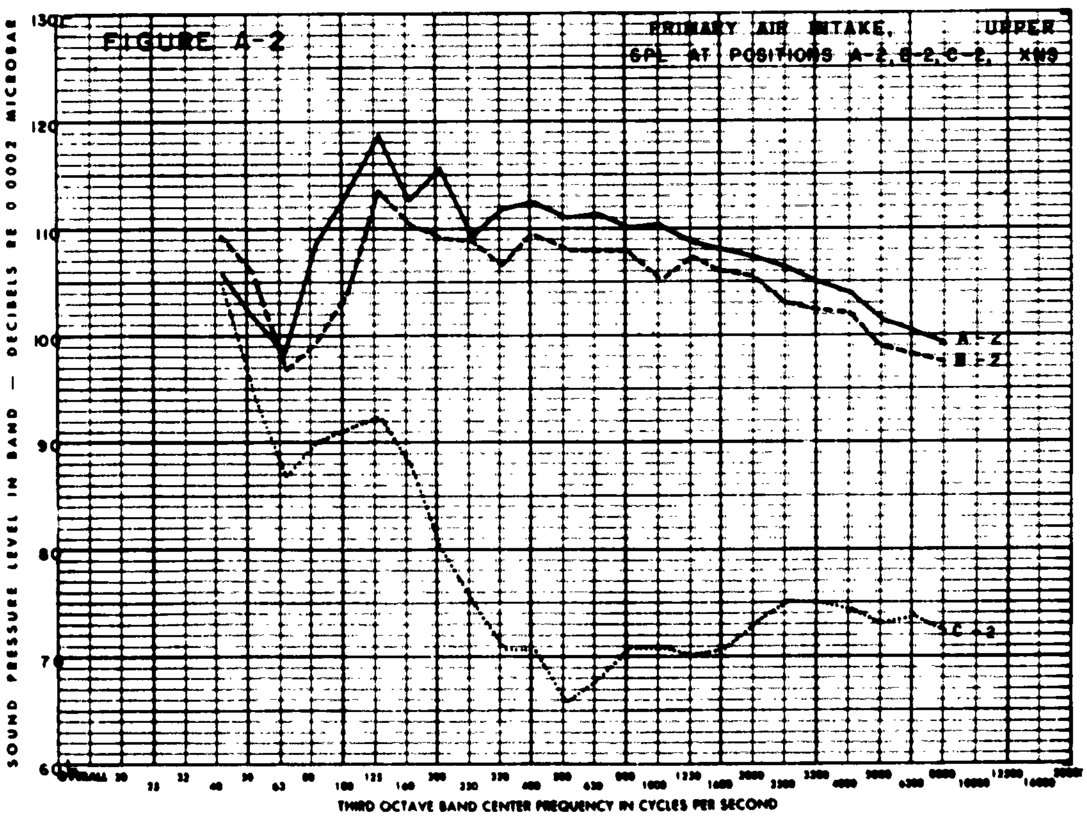
FIGURE A-2
PRIMARY AIR INTAKE, UPPER
SPL AT POSITIONS A-2, B-2, C-2, XMS
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND
A-2
B-2
C-2

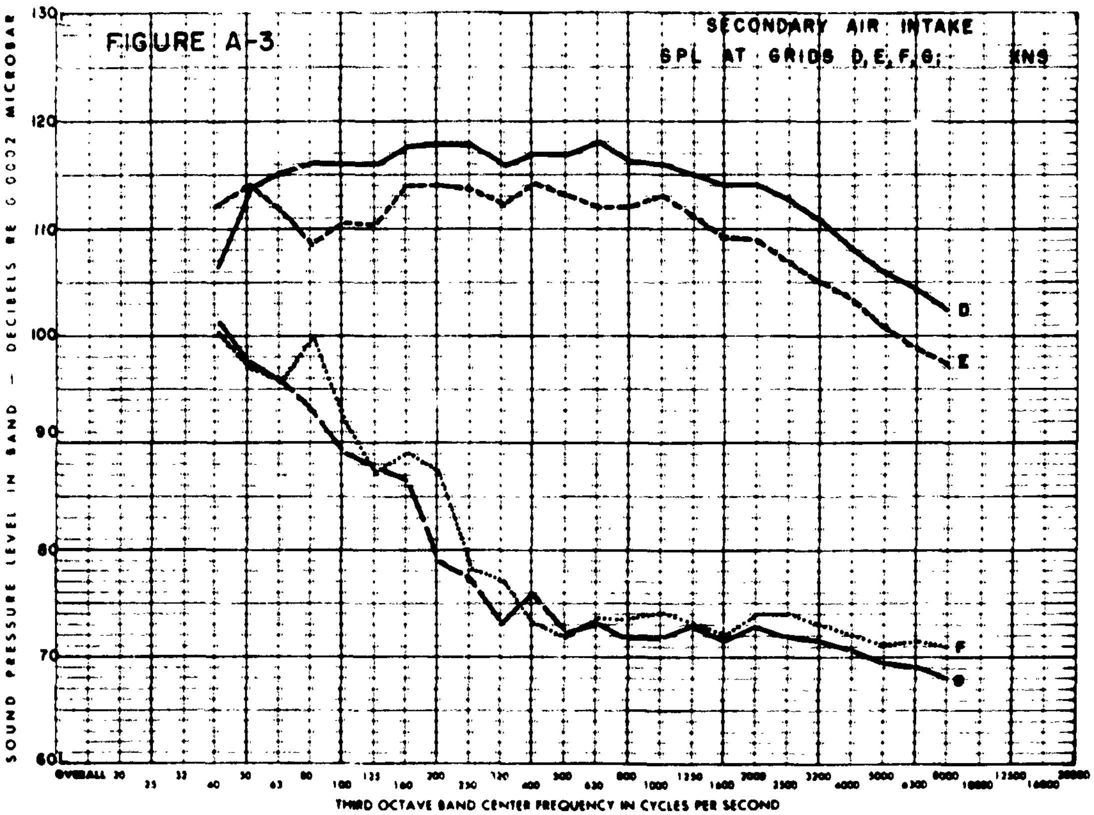
FIGURE A-3
SECONDARY AIR INTAKE
SPL AT GRIDS D, E, F, G; XNS
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND
D
E
F
G

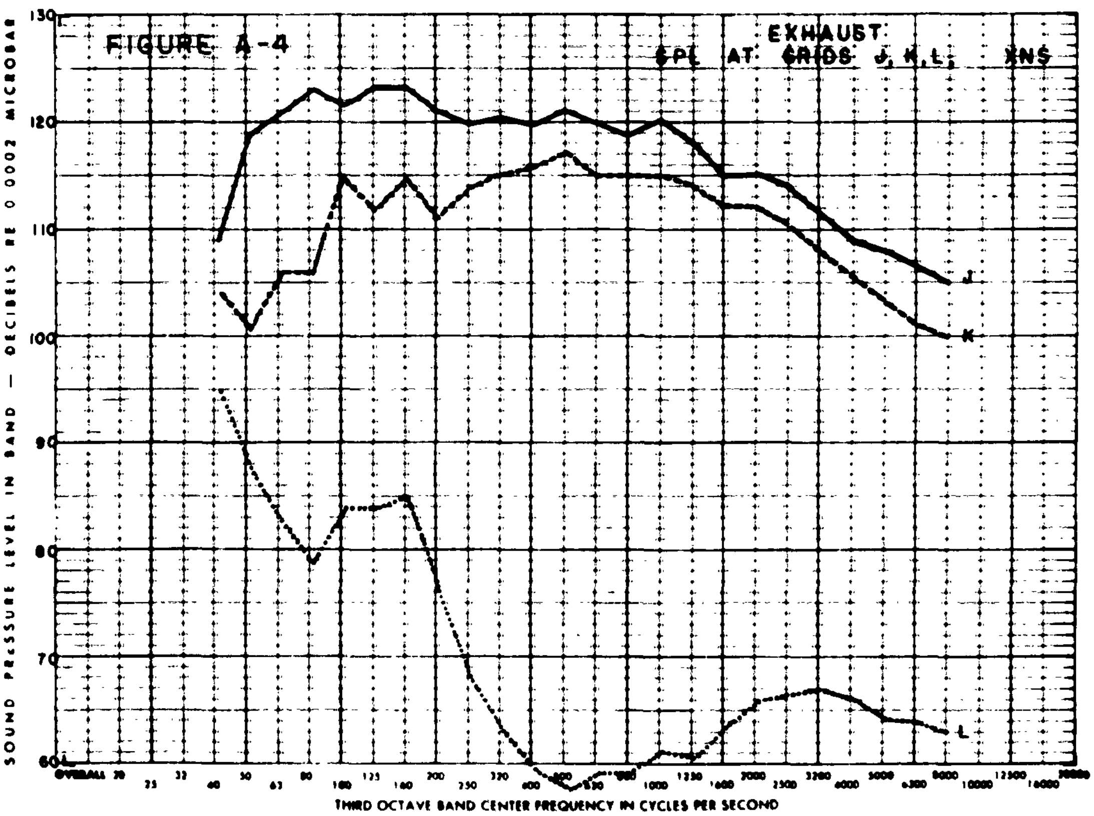
FIGURE A-4
EXHAUST
SPL AT GRIDS J, K, L; XNS
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND
J
K
L

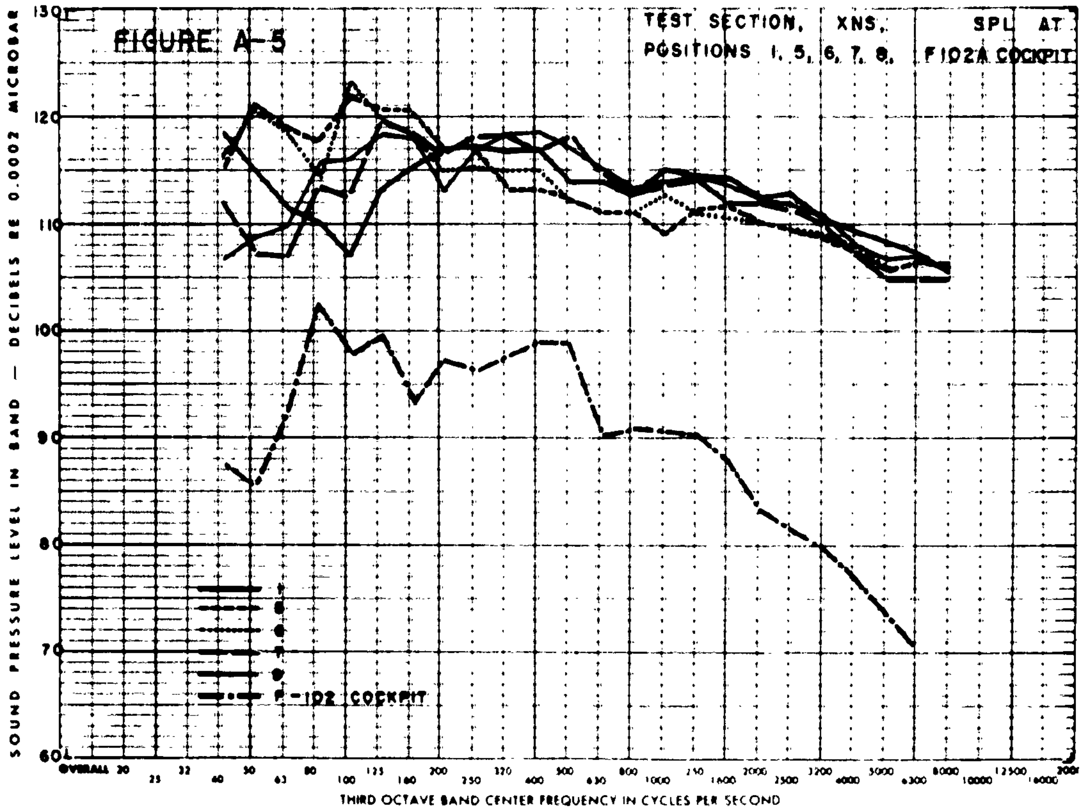
FIGURE A-5
TEST SECTION, XNS, POSITIONS 1, 5, 6, 7, 8, SPL AT F102A COCKPIT
F-102 COCKPIT
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

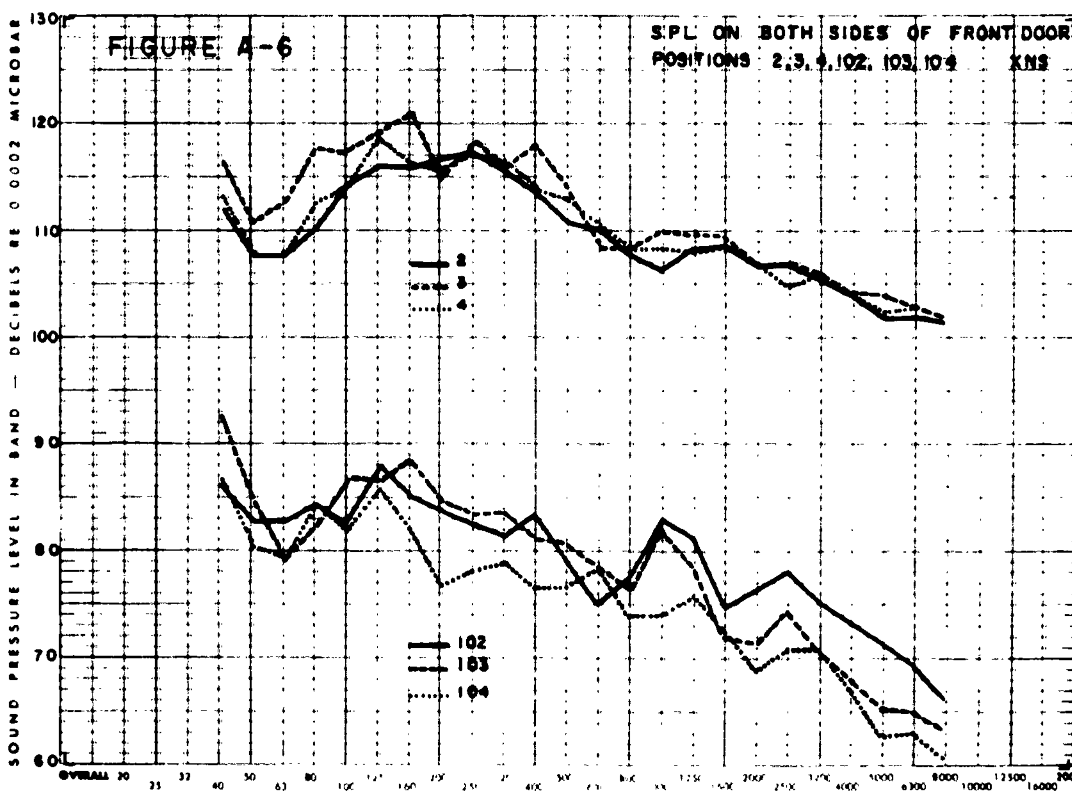
FIGURE A-6
SPL ON BOTH SIDES OF FRONT DOOR
POSITIONS 2, 3, 4, 102, 103, 104 XNS
2
3
4
102
103
104
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR

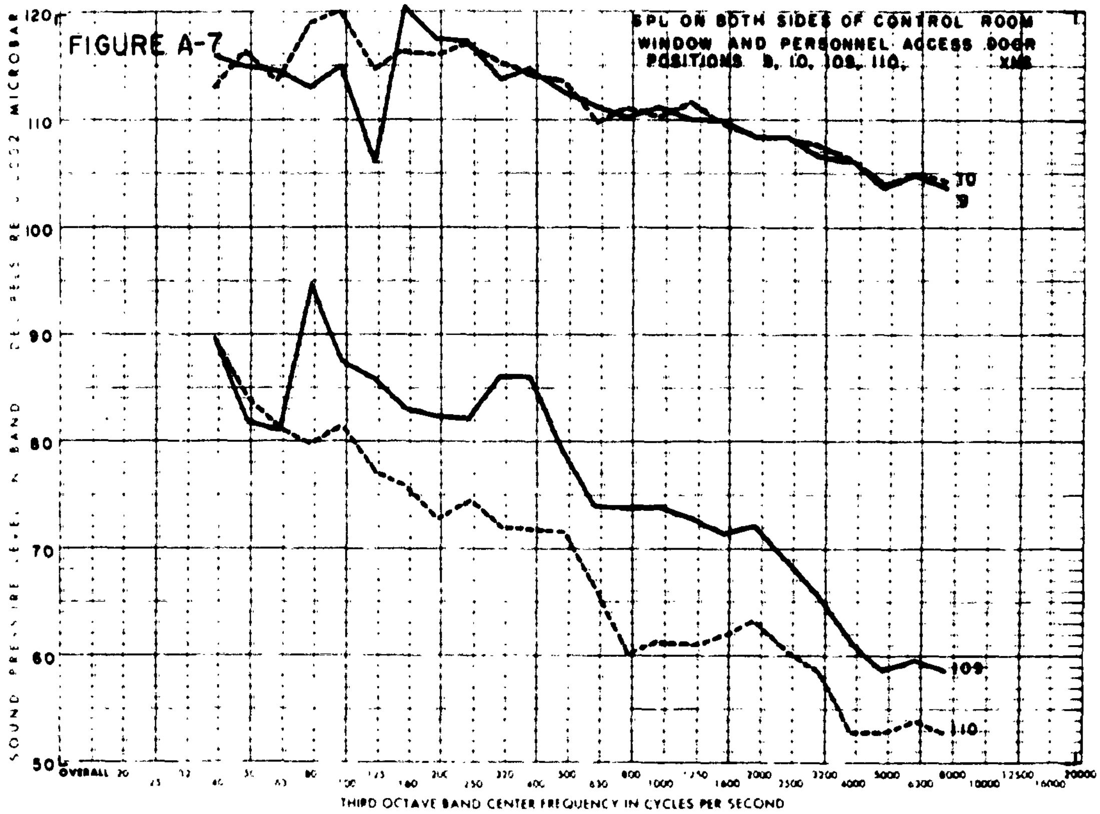
FIGURE A-7
SPL ON BOTH SIDES OF CONTROL ROOM WINDOW AND PERSONNEL ACCESS DOOR POSITIONS 9, 10, 109, 110.
10
9
109
110
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

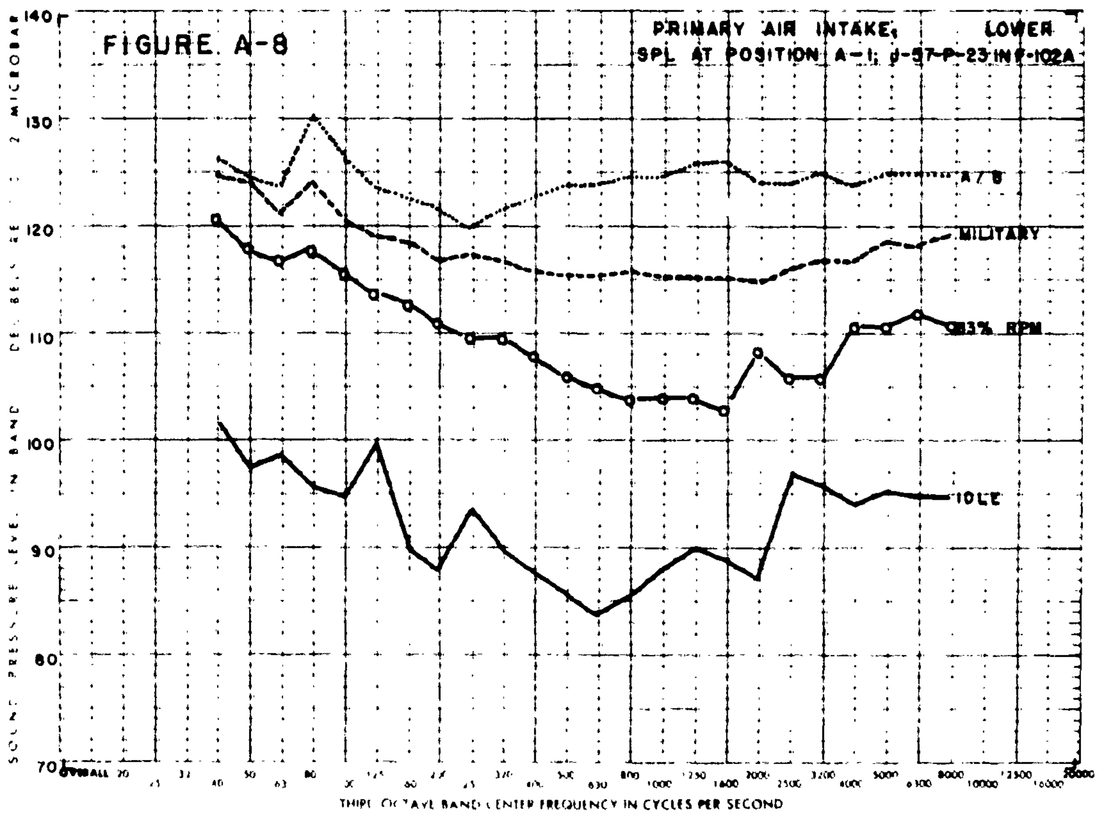
FIGURE A-8
PRIMARY AIR INTAKE, LOWER
SPL AT POSITION A-1; J-57-P-23 IN F-102A
A/B
MILITARY
83% RPM
IDLE
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

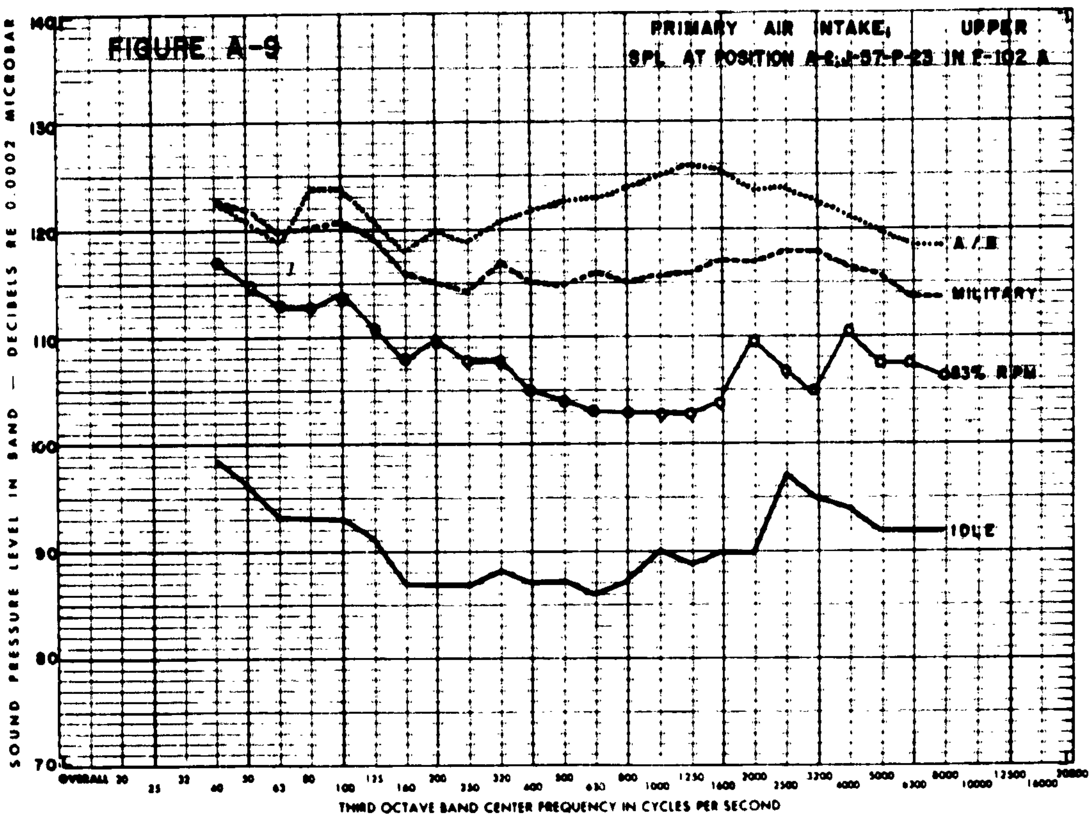
FIGURE A-9
PRIMARY AIR INTAKE, UPPER
SPL AT POSITION A-2, J-57-P-23 IN F-102 A
A/B
MILITARY
83% RPM
IDLE
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

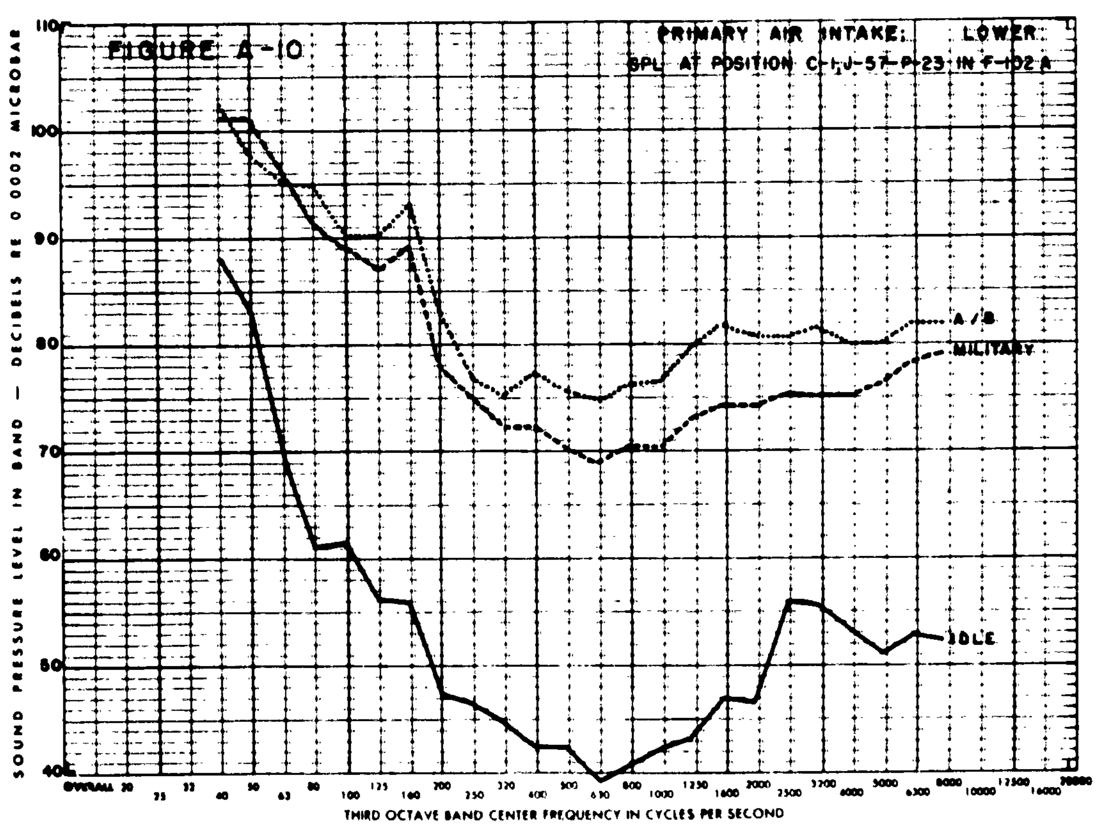
FIGURE A-10
PRIMARY AIR INTAKE; LOWER
SPL AT POSITION C-1, J-57-P-23 IN F-102 A
A/B
MILITARY
IDLE
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

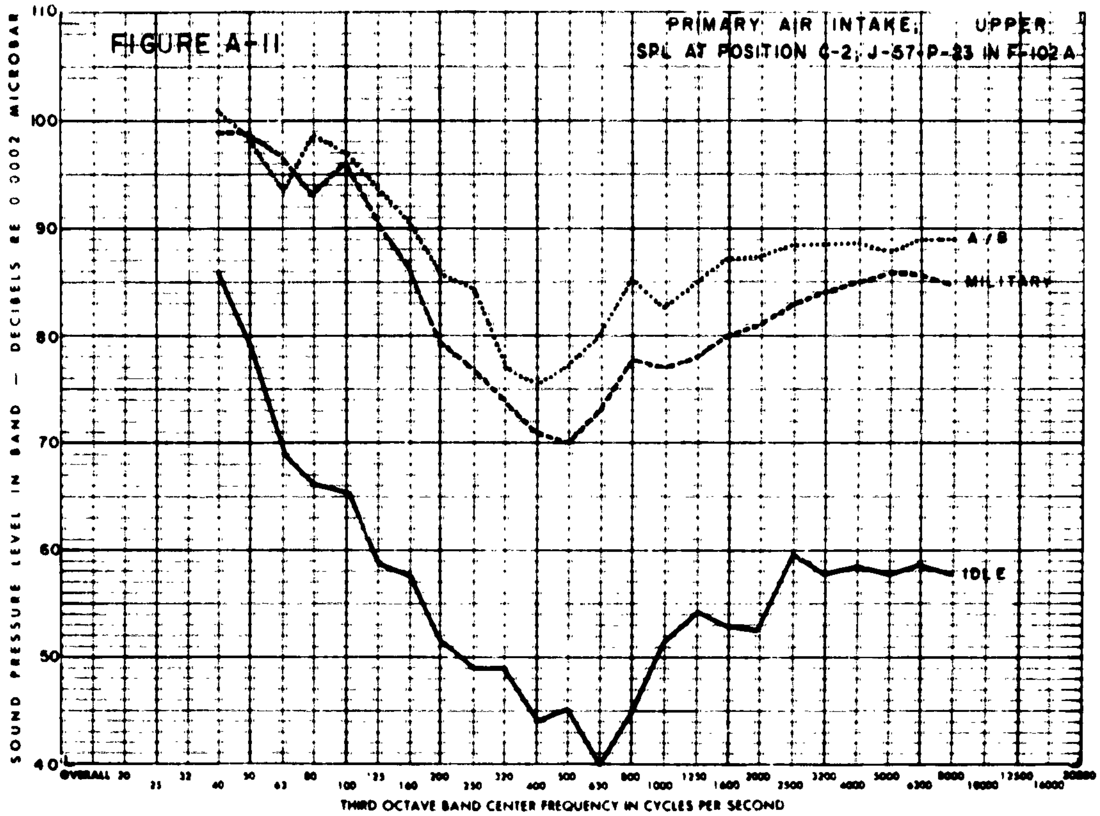
FIGURE A-11
PRIMARY AIR INTAKE; UPPER
SPL AT POSITION C-2; J-57-P-23 IN F-102A
A/B
MILITARY
IDLE
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

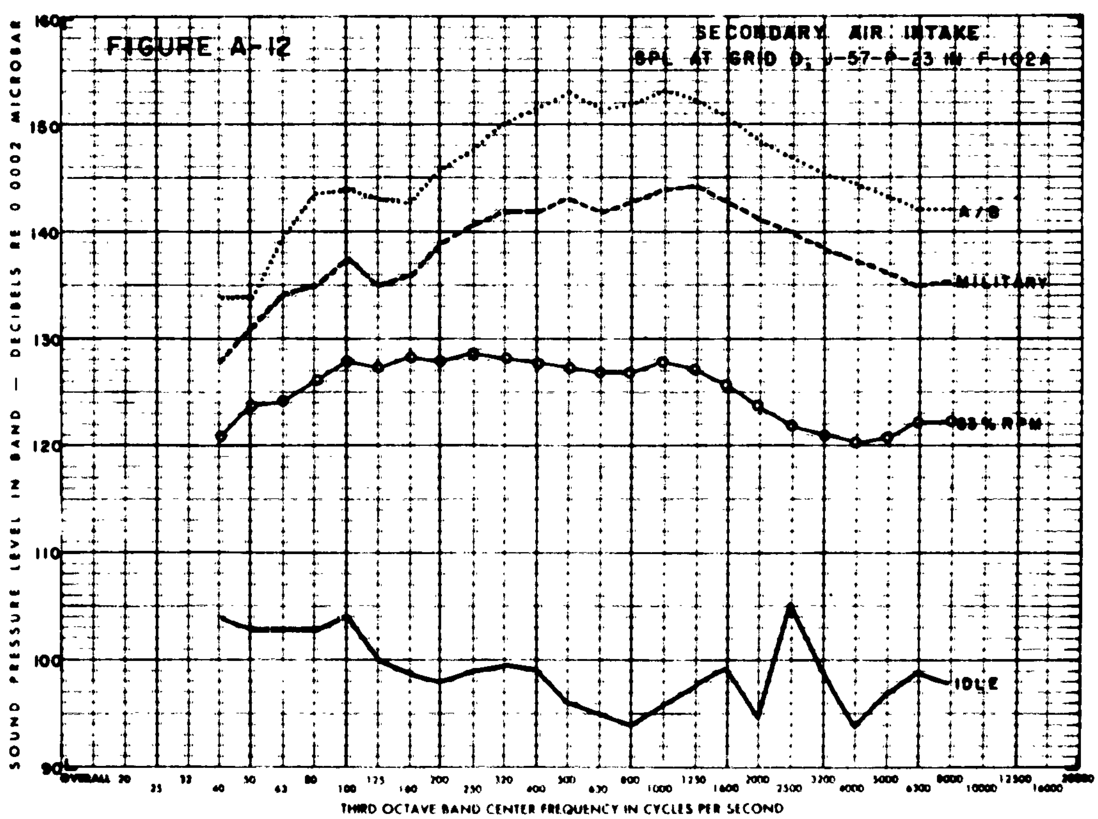
FIGURE A-12
SECONDARY AIR INTAKE
SPL AT GRID D; J-57-P-23 IN F-102A
A/B
MILITARY
IDLE
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

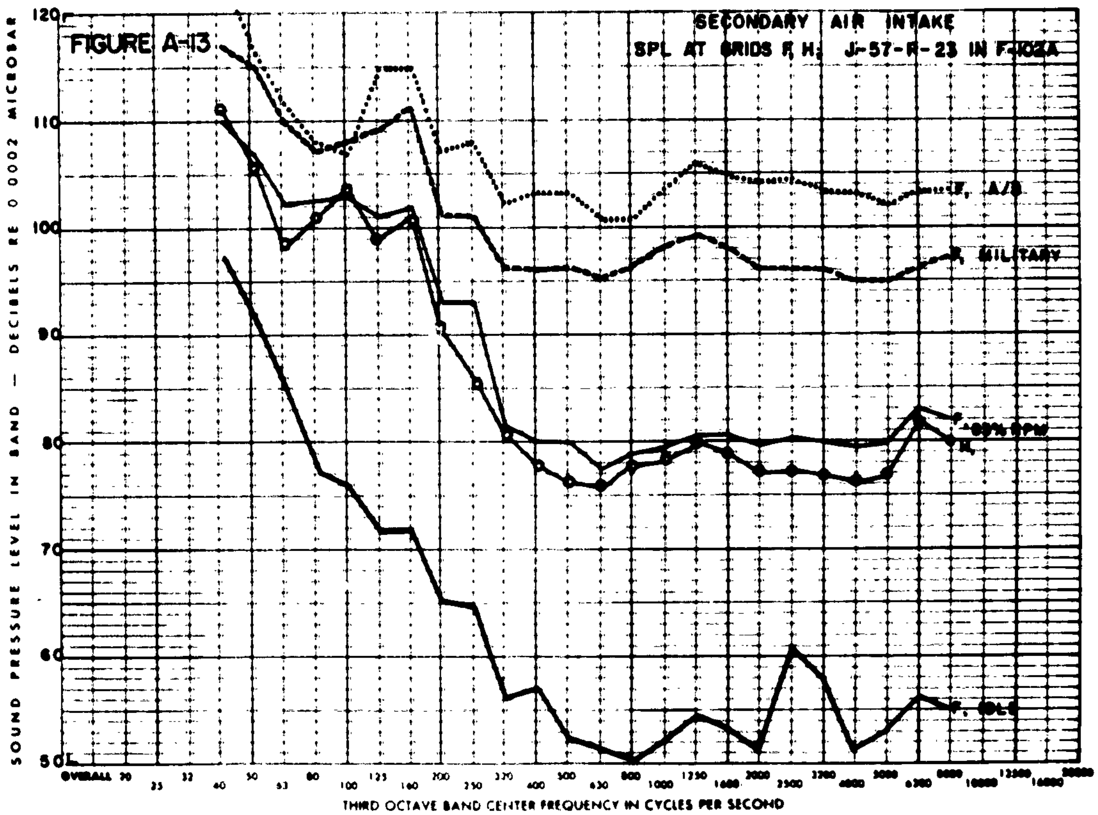
FIGURE A-13
SECONDARY AIR INTAKE
SPL AT GRIDS F, H; J-57-P-23 IN F-102A
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

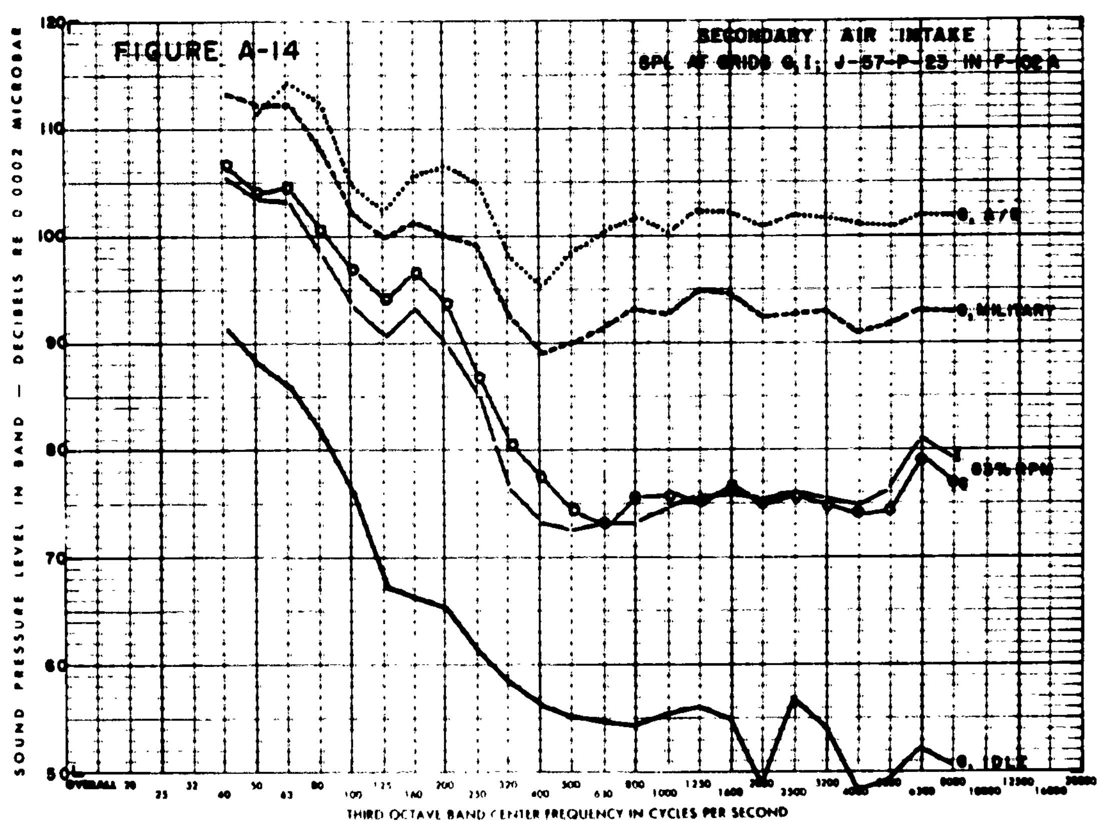
FIGURE A-14
SECONDARY AIR INTAKE
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

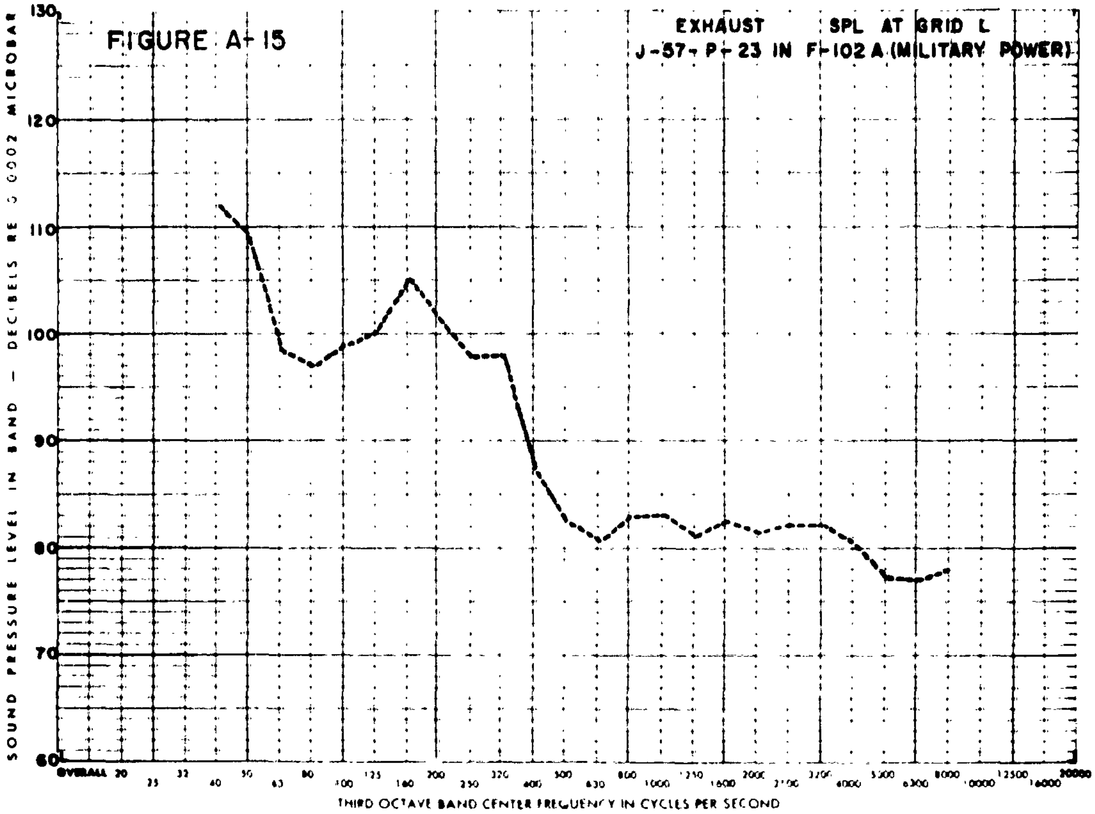
FIGURE A-15
EXHAUST SPL AT GRID L
J-57-P-23 IN F-102 A (MILITARY POWER)
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR
130
120
110
100
90
80
70
60
OVERALL 20 25 32 40 50 63 80 100 125 160 200 250 320 400 500 630 800 1000 1250 1600 2000 2500 3200 4000 5000 6300 8000 10000 12500 16000 20000
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

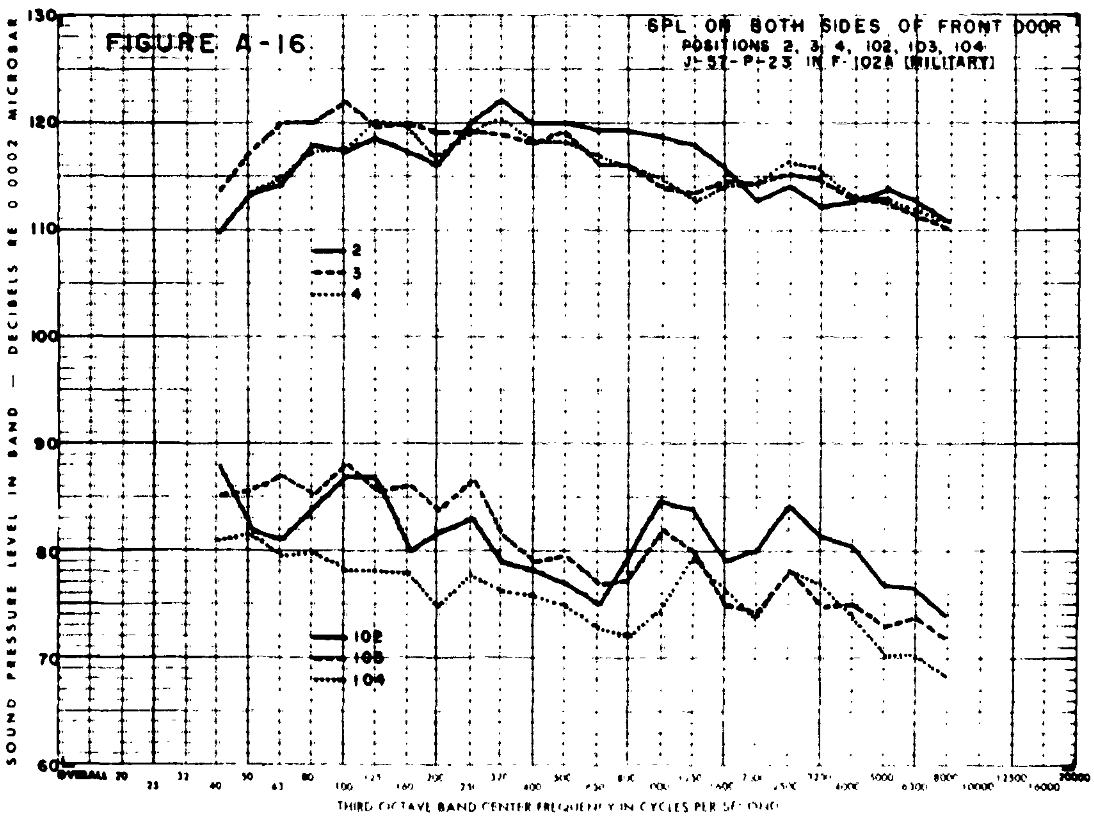
FIGURE A-16
SPL ON BOTH SIDES OF FRONT DOOR
POSITIONS 2, 3, 4, 102, 103, 104
J-57-P-23 IN F-102A (MILITARY)
2
3
4
102
103
104
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR
130
120
110
100
90
80
70
60
OVERALL 20 25 32 40 50 63 80 100 125 160 200 250 320 400 500 630 800 1000 1250 1600 2000 2500 3200 4000 5000 6300 8000 10000 12500 16000 20000
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

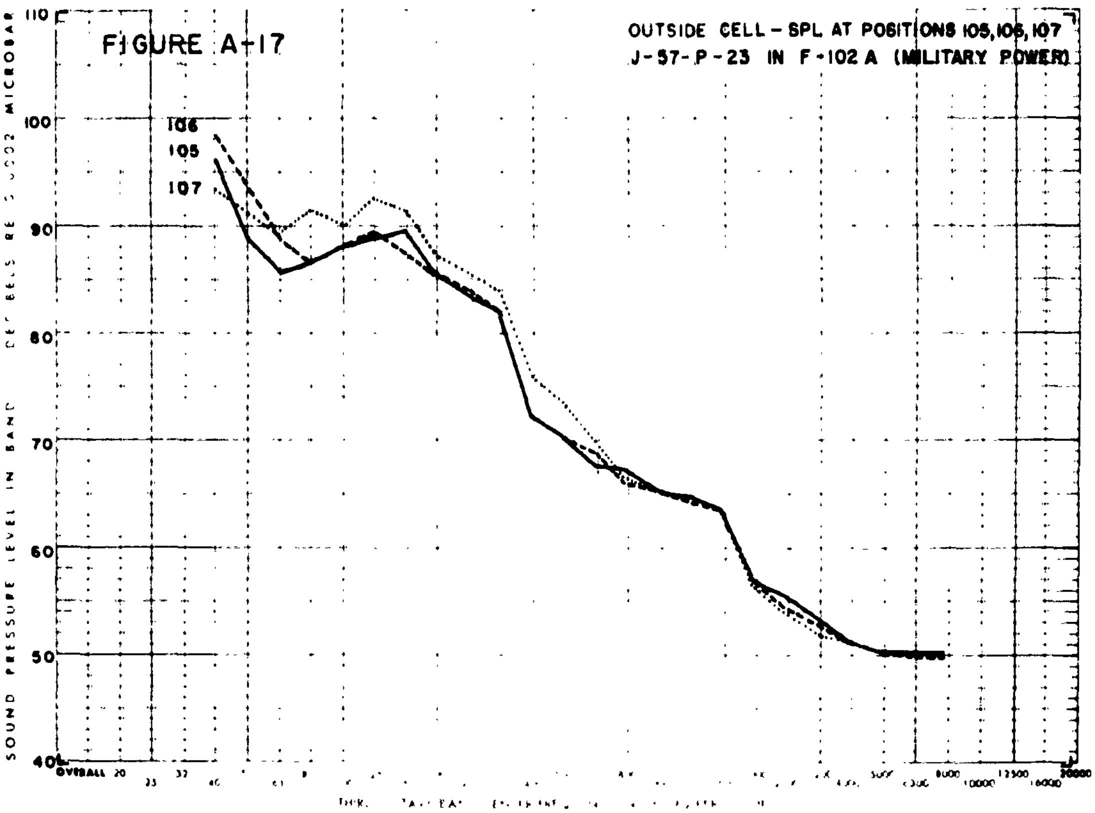
FIGURE A-17
OUTSIDE CELL - SPL AT POSITIONS 105,106,107
J-57-P-23 IN F-102 A (MILITARY POWER)
106
105
107
SOUND PRESSURE LEVEL IN BAND - DECIBELS RE 0.0002 MICROBAR
110
100
90
80
70
60
50
40
OVERALL

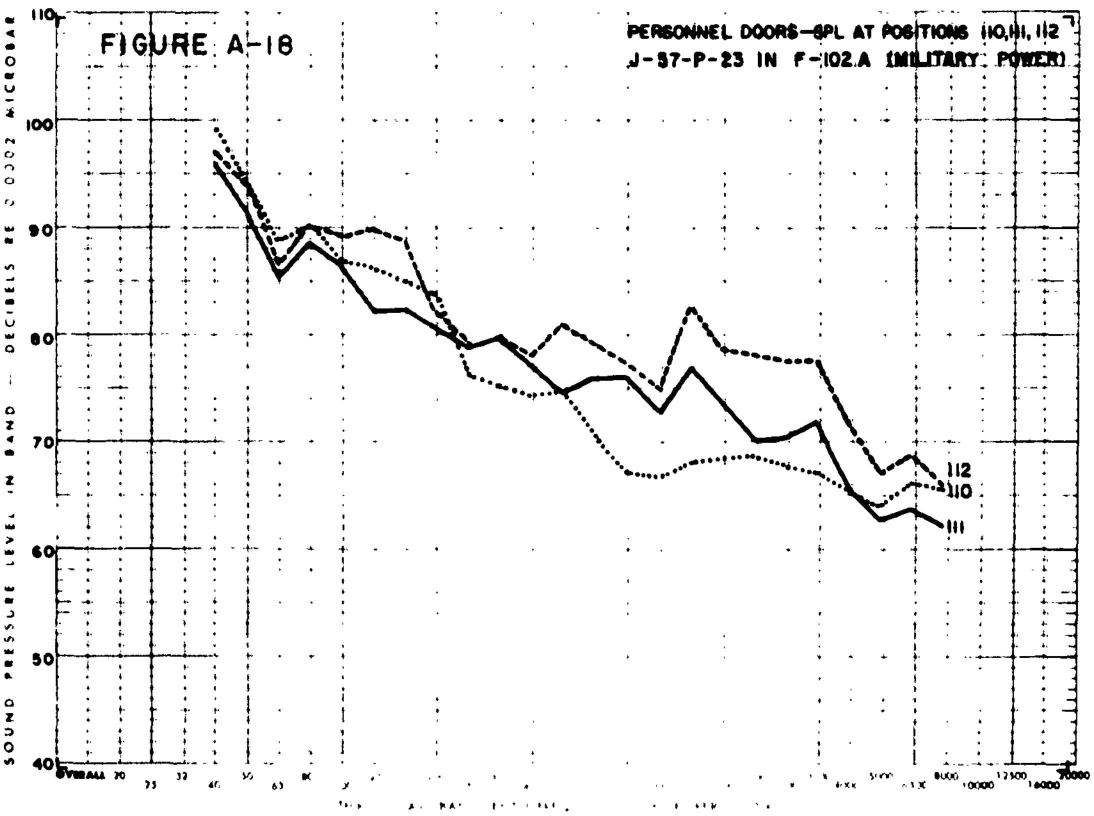
FIGURE A-18
PERSONNEL DOORS—SPL AT POSITIONS 110,111,112
J-57-P-23 IN F-102A (MILITARY POWER)
112
110
111
SOUND PRESSURE LEVEL IN BAND - DECIBELS RE 0.0002 MICROBAR
110
100
90
80
70
60
50
40
OVERALL

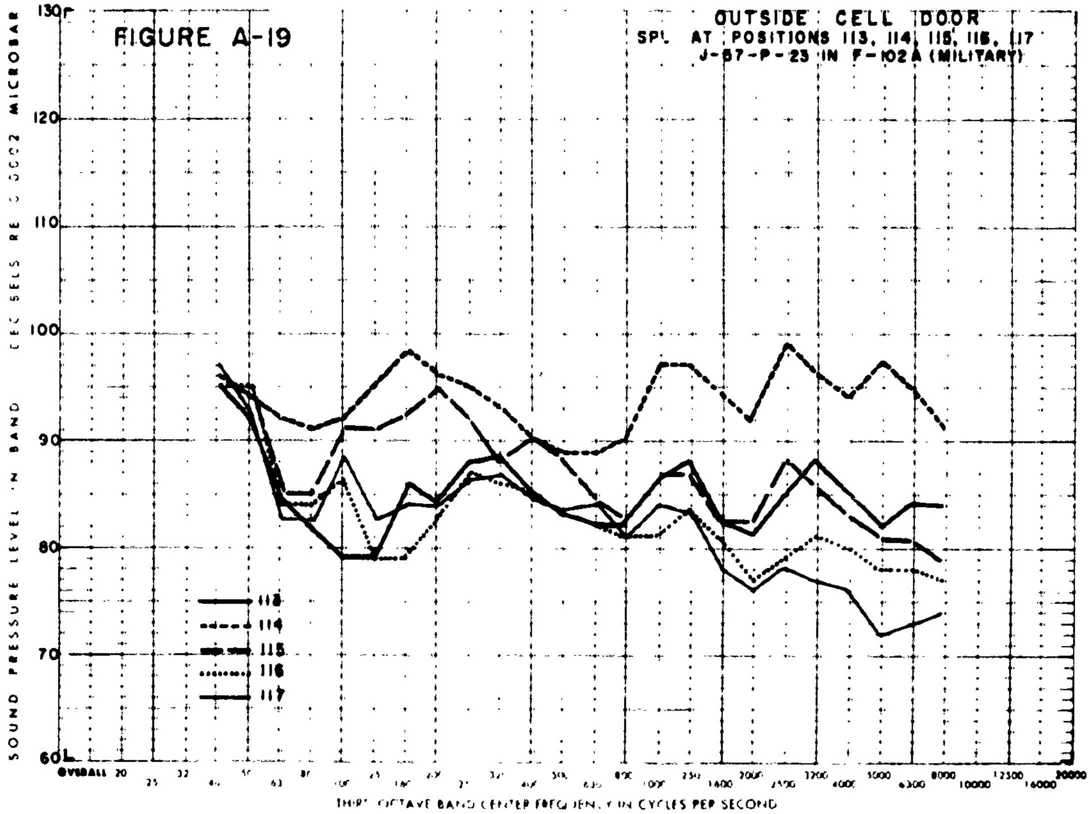
FIGURE A-19
OUTSIDE CELL DOOR
SPL AT POSITIONS 113, 114, 115, 116, 117
J-57-P-23 IN F-102A (MILITARY)
SOUND PRESSURE LEVEL IN BAND
113
114
115
116
117
OVERALL
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

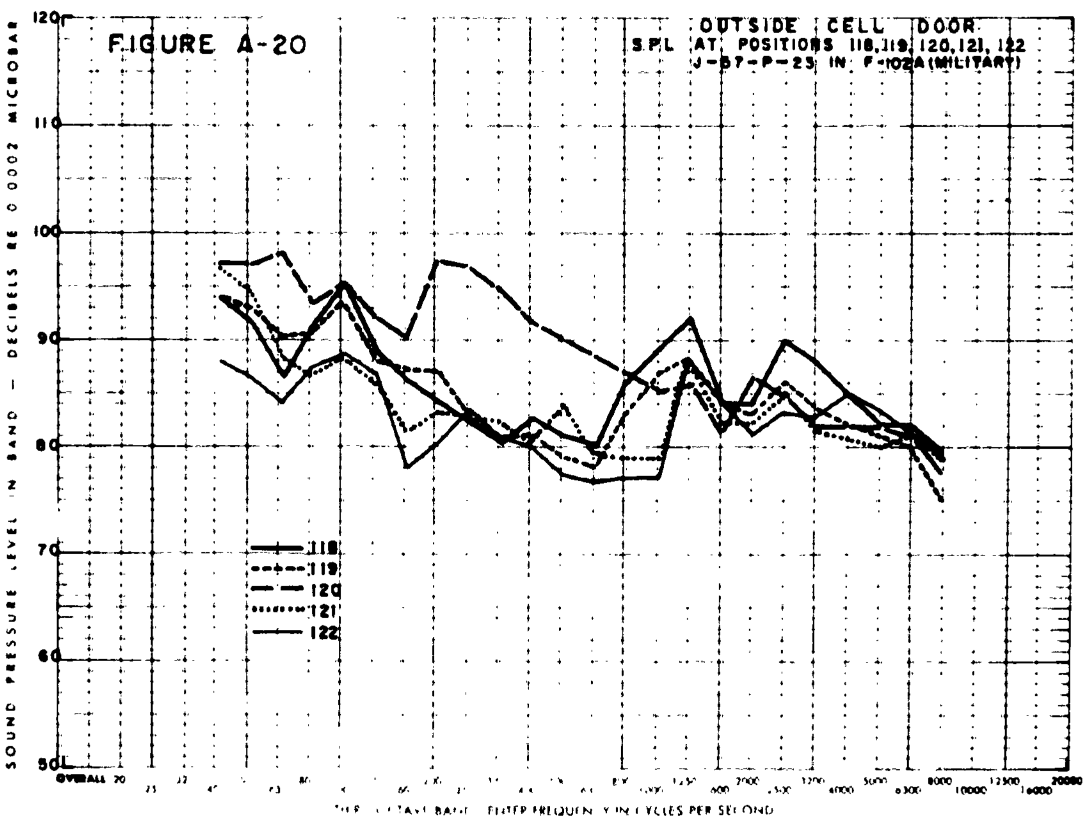
FIGURE A-20
OUTSIDE CELL DOOR
S.P.L AT POSITIONS 118, 119, 120, 121, 122
J-57-P-23 IN F-102A (MILITARY)
SOUND PRESSURE LEVEL IN BAND — DECIBELS RE 0.0002 MICROBAR
118
119
120
121
122
OVERALL

WADC TN 57-390

Bolt Beranek and Newman Inc., Cambridge, Massachusetts
ACOUSTICAL EVALUATION OF F-102 PRODUCTION SILENCER-CONVAIR, SAN DIEGO, by David N. Keast. November 1961. 57p. incl. illus., tables, 12 refs. (Proj. 7210; Task 71708) Unclassified report

The F-102 production silencer enclosure at Convair-San Diego has been evaluated acoustically. This silencer is similar to a turbojet engine test cell, but is designed to enclose a complete aircraft. Measurements of sound pressure level in and around the silencer are reported, and the noise reductions of the various elements of the acoustical treatment, as

(over)

UNCLASSIFIED

I. Keast, David N.
II. Aeronautical Systems Division, Aerospace Medical Laboratory, Wright-Patterson Air Force Base, Ohio
III. Contract No. AF 33(616)-3938

UNCLASSIFIED

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